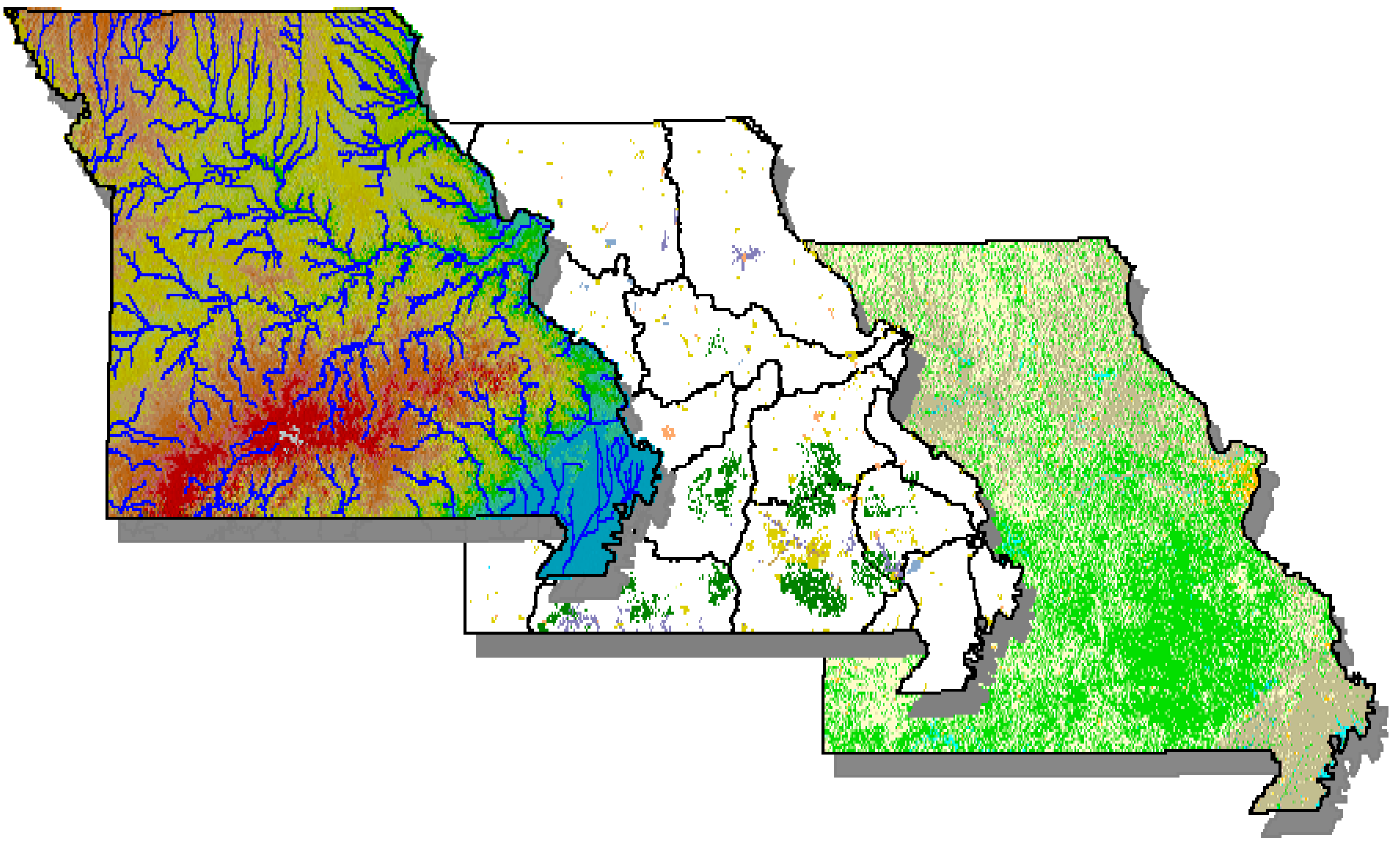
THE AQUATIC COMPONENT OF GAP ANALYSIS: A MISSOURI PROTOTYPE

Final Report



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THE AQUATIC COMPONENT OF GAP ANALYSIS: A MISSOURI PROTOTYPE

FINAL REPORT

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Scott P. Sowa, Principal Investigator

David D. Diamond, Co-Principal Investigator

Robbyn Abbitt, Conservation Assessment

Gust M. Annis, Ecological Classification and Distribution Modeling

Taisia Gordon, Stewardship and Conservation Assessment

Michael E. Morey, Range Mapping and Distribution Modeling

Gina R. Sorensen, Habitat Affinity Documentation

Diane True, Stewardship and Conservation Assessment

Missouri Resource Assessment Partnership
University of Missouri
Columbia, MO 65201

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University of Missouri-Columbia

Submitted by:
Scott P. Sowa

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The National Gap Analysis Program (GAP) was initiated in 1988 to provide a coarse-filter assessment strategy for identifying and prioritizing biodiversity conservation needs. While GAP has made enormous strides in developing and conducting coarse-filter biodiversity assessments for terrestrial ecosystems, much less has been accomplished for aquatic ecosystems. The need for developing an aquatic component of GAP was recognized as early as 1993, when Congress allocated the funds needed to support such an effort. Those funds, however, were rescinded. GAP did manage to initiate an aquatic component of the program in 1995 with a pilot in the upper Allegheny River Basin in Western New York. In 1997, in cooperation with the Missouri Resource Assessment Partnership (MoRAP) and financial assistance by the USGS National Water Quality Assessment Program, the U.S. Department of Defense-Legacy Program, and the Missouri Department of Conservation, GAP initiated a statewide pilot project for the state of Missouri. Both of these projects focused on riverine ecosystems. This report summarizes the approach, results and significant findings of the Missouri pilot project.

When it comes to freshwater ecosystems the North American continent, and in particular the United States, harbors an astounding proportion of the world's freshwater species. Despite this distinction, North America and the United States are facing a freshwater biodiversity crisis. While much attention has been focused on the global losses of terrestrial biodiversity especially in tropical ecosystems, comparatively little attention has been given to the alarming declines in freshwater biodiversity. Yet, it is encouraging to see that within the last decade more and more attention has been focused on conserving freshwater biodiversity. A critical first step to slowing the loss of biodiversity is identifying gaps in existing efforts to conserve freshwater biodiversity across the landscape and then prioritizing opportunities to fill these gaps. This is the overall goal of the USGS National Gap Analysis Program and this project.

The principal goal of our project was to identify riverine ecosystems and species not adequately represented (i.e., gaps) in the matrix of conservation lands in Missouri. Another goal was to develop ways of integrating the terrestrial and aquatic components of gap analysis. In addition, we wanted to provide spatially explicit data that could be used by natural resource professionals, legislators, and the public to make more informed decisions for prioritizing opportunities to fill these conservation gaps and to devise strategic approaches for developing effective long-term biodiversity conservation plans. Furthermore, as a pilot project for a national program, we also had the goal of developing a broadly applicable gap analysis methodology. We addressed this goal by ensuring that we utilized nationally standardized and available geospatial data wherever possible and also by devising a flexible conservation assessment methodology, which can accommodate the differences in data availability (e.g., biological) that exists among states across the United States.

Several geospatial and tabular datasets were developed to meet the information/data needs for identifying conservation gaps and subsequently prioritizing opportunities to fills these gaps: a) maps of a hierarchical classification of riverine ecosystems, b) predicted species distribution maps, c) ownership and stewardship maps, and d) maps of human stressors. These data were then used to conduct a gap analysis of both biotic and abiotic conservation targets and also to develop a statewide freshwater biodiversity conservation plan.

The data and methods developed and used in this project go well beyond anything done to date in any part of the world. Our assessment methods incorporated both ecological and evolutionary contexts that are so critical to conserving biodiversity, which heretofore have been largely ignored. Also, the high resolution biological and stewardship data (i.e., individual stream segment) coupled with the tremendous amount of geospatial data on human stressors enabled us to precisely pinpoint specific areas (clusters of stream segments) that are critical to the long term maintenance of biodiversity within Missouri.

Even though the basic goal and objectives of the terrestrial and aquatic components of gap are the same, there is a major obstacle to upfront integration of the gap analyses. The foremost obstacle to a fully integrated terrestrial and aquatic gap analysis pertains to the fact that if we are going to conserve biodiversity we must conserve ecosystems. Traditionally, ecoregions have served as the geographic framework for defining terrestrial ecosystems and conserving terrestrial biodiversity. While ecoregions do a good job of accounting for structural and functional differences in freshwater ecosystems, they do not account for important compositional differences (species and genetic composition) that have resulted from isolation mechanisms largely related to historical and contemporary drainage patterns. Defining ecosystems in freshwater environments requires the integration of ecoregion and watershed boundaries. Consequently, separate geographic frameworks are needed in order to appropriately place terrestrial and aquatic ecosystems into their proper ecological and evolutionary contexts. This is why we developed a separate aquatic ecological classification framework for our project. This fundamental difference should not be viewed as an impediment to conserving biodiversity, merely and obstacle. Separate conservation assessments or gap analyses can be performed and the results then integrated a posteriori into an overall assessment or analysis. This is the approach we have taken in Missouri.

The results of the gap analysis are not encouraging. However, the results from the conservation planning efforts provide hope that relatively intact ecosystems still exist even in highly degraded landscapes. Results also suggest that a wide spectrum of the abiotic and biotic diversity can be represented within a relatively small portion of the total resource base, with the understanding that for riverine ecosystems the area of conservation concern is often substantially larger than the identified priority locations. Selecting and mapping priority riverscapes for conservation is the first step toward effective biodiversity conservation. Yet, establishing geographic priorities is only one of the many steps in the overall process of achieving real conservation. Achieving the ultimate goal of conserving biodiversity will require vigilance on the part of all responsible parties, with particular attention to addressing and coordinating the many remaining logistical tasks.

We have held nine training workshops in order to provide training to individuals interested in implementing our methods in their respective states. Through these training workshops we have provided training to more than 50 individuals representing numerous state and federal agencies and academic institutions. This training has helped with the establishment of aquatic gap projects in 20 states.

ACKNOWLEDGEMENTS

We first want to thank to John Mosesso of the US Geological Survey (USGS) Biological Resource Division and Kevin Gergely of the USGS National Gap Analysis Program for their unwavering support of our project over the years. We also want to thank several past and present staff of the National Gap Analysis Program. Specifically, we want to thank Mike Jennings for selecting Missouri as one of the first pilot projects for the aquatic component of GAP and giving MoRAP the chance to take on this task. We also need to thank Mike and Patrick Crist for their invaluable advice and the many thoughtful theoretical and technical discussions during the early stages of the project. We are very grateful to Elizabeth Brackney, Ree Brannon, and Becky Sorbel for all of their administrative support over the years.

The USGS National Water Quality Assessment Program, the US Department of Defense Legacy Program, and the Missouri Department of Conservation (MDC) provided funding for this project. We are especially grateful to Leslie Orzetti for her support and administration of this project through the Legacy Program. Joe Dillard and Gary Novinger, of MDC, deserve special thanks for their foresight and fortitude in garnering support for this project throughout their agency and Missouri.

To say that this project was a collaborative effort would be a gross understatement. There are an overwhelming number of people who have generously contributed their time and effort to this project and without whom this project could never have been completed. We sincerely regret any omissions, because everyone who has contributed deserves a special “Thank You”!

We are deeply indebted to all of the past and present staff at The Nature Conservancy’s Freshwater Initiative Program for their foundational work on developing a hierarchical ecological classification for freshwater ecosystems. We would especially like to thank Johnathan Higgins, Mary Lammert-Khoury, and Denny Grossman (NatureServe) for all of their open collaboration on this difficult task over the years. A special thanks to Mary and Johnathan, Paul Angermeier (Virginia Tech University), Paul Seelbach (Michigan DNR), and Randy Sarver (Missouri DNR) for all of their thought provoking discussions on this topic! Tom Fitzugh and Mark Caldwell (MDC) also deserve special thanks for their diligent work on overcoming the many technical hurdles involved with trying to efficiently map classification units within a GIS. Pamela Haverland (USGS), Jeri Peck (EcoStats), and John Stanovick (MDC, now US Forest Service) provided invaluable statistical assistance that was so critical to the classification process.

This project could not have been possible without the countless hours of fieldwork by those individuals over the past 100 years that have tirelessly gone into the wilds of Missouri to make the thousands of biological collections used as the basis for predictive models eventually developed in this project. We must also thank the many agencies and individuals that took the time to organize and share these collection records with us. Especially, the MDC, Missouri Department of Natural Resources, USGS, EPA Region 7, University of Missouri, and Ronald Oesch. Special thanks go out to those individuals that took the time to review the many distribution maps created during this project; Sue Brundermann, Alan Buchanan, Bob DiStefano, Scott Faiman, Ronald Oesch, and William Pflieger. Dr. Pflieger deserves special recognition for sharing his tremendous knowledge of Missouri’s stream resources with us. Pamela Haverland and John

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We also need to thank all of the people working on aquatic GAP projects throughout the nation. Your questions and suggestions sharpened our thinking and improved our methods and the final product. We sincerely look forward to our continued collaboration in the future.

Finally, we would like to thank all of the MoRAP partner agencies and their staff that have helped in so many ways with this project, through work on committees, offering assistance or advice, and being a sounding board when difficult decisions had to be made.

LIST OF TABLES

LIST OF FIGURES

Introduction

The National Gap Analysis Program (GAP) was initiated in 1988 to provide a coarse-filter assessment strategy for identifying and prioritizing biodiversity conservation needs (Scott et al. 1993). While GAP has made enormous strides in developing and conducting coarse-filter biodiversity assessments for terrestrial ecosystems, much less has been accomplished for aquatic ecosystems. The program's initial focus on terrestrial vertebrates and vegetation types was a choice based on what was achievable at that early time in the history of the program (Jennings 1999). In principle, GAP is committed to developing biogeographic information and assessment strategies for all major ecosystem types (Jennings 1999).

The need for developing an aquatic component of GAP was recognized as early as 1993, when Congress allocated the funds needed to support such an effort. Those funds, however, were rescinded. GAP still managed to initiate development of an aquatic component of the program in 1995 with the start of a pilot in the upper Allegheny River Basin in Western New York, which was completed in 1999 (Meixler and Bain 1999). In 1997 in cooperation with the Missouri Resource Assessment Partnership (MoRAP) and financial assistance by the USGS National Water Quality Assessment Program, the U.S. Department of Defense and the Missouri Department of Conservation, GAP initiated a statewide pilot project for the state of Missouri. Both of these projects focused on riverine ecosystems. This report summarizes the approach, results and conclusions of the Missouri pilot project.

How This Report is Organized

This report is a summation of a complex scientific project. Its organization follows the general chronology of the project. It departs from standard scientific reporting by mixing results and discussion within individual chapters. This was done to provide users of the data with a more concise and complete reference for each data and analysis product.

We begin with an overview of freshwater biodiversity in the United States followed by a section, which reviews the GAP mission, concept, and limitations. We then review the principle goal and objectives of this project and the scope/focus of our project. Next is an overview of the information/data requirements for ecologically-based conservation planning in general and more specifically conducting a gap analysis for riverine ecosystems. We then discuss the issue of a why we believe it is not advisable to conduct a fully integrated aquatic and terrestrial gap analysis. Next are chapters on the geospatial and tabular datasets that we developed to meet the information/data needs for identifying conservation gaps and subsequently prioritizing opportunities to fills these gaps: a) classifying riverine ecosystems, b) predicting species distributions and biological potential, c) stewardship mapping, and d) accounting for human stressors. Then we provide overview of the methods and results of a statewide freshwater biodiversity assessment conducted for Missouri. We then cover the methods and results of our gap analysis. Finally, we provide an overview of the training workshops we have held and the publications and presentations we have given pertaining to our work on this project.

Overview of Freshwater Biodiversity in the United States

Rivers and streams play an important role in shaping and sustaining human existence on earth. They provide critical ecosystem services such as industrial and municipal water supply, renewable energy production, irrigation, flood control, transportation, commercial fisheries, and the assimilation of human wastes (Allan and Flecker 1993; Doppelt et al. 1993). Rivers and streams also have immense recreational value, from "consumptive" uses such as sport fishing, to "non-consumptive" uses such as rafting and canoeing, swimming, streamside hiking, camping and wildlife observation, and the general appreciation of scenic values and aesthetics (Doppelt et al. 1993). The global economic value of these and other services has been estimated to be in the trillions of dollars (Revenga et al. 2000).

At any given time only about 0.01% of the total volume of water on Earth occurs in rivers and lakes. Yet, it has been estimated that anywhere from 25% (Stiassny 1996) to over 50% (Abramovitz 1996) of the global vertebrate diversity is concentrated into this tiny fraction of the biosphere with the vast majority of this diversity occurring within and along riverine ecosystems. Unfortunately, most conservation lands in the United States are situated in the uplands away from these "ribbons" of extraordinary biological diversity due to the fact that the lands adjacent to rivers and streams are the most easily developed and have high economic value for housing, agriculture, or other human uses.

When it comes to freshwater ecosystems the North American continent, and in particular the United States, harbors an astounding proportion of the world's freshwater species (Warren and Burr 1994; Master et al. 1998; Olson and Dinerstein 1998). Ten percent of all the freshwater fish species, 30% of all the freshwater mussels, and an astounding 61% of all the freshwater crayfish that have been described worldwide are found within the United States (Page and Burr 1991; Williams et al. 1993; Taylor et al. 1996; Master et al.1998). Even more impressive proportions exist for other taxa (e.g., stoneflies, dragonflies, mayflies) (Master et al. 1998). Statistics for these groups are certainly influenced to some degree by global disparities in collection effort afforded these taxa and therefore likely inflate the global distinctiveness of freshwater species richness of the United States. Nonetheless, it is quite apparent, from a global perspective, that the United States is a global "hot spot" for freshwater biodiversity, especially when comparisons are restricted only to temperate regions.

Despite these impressive statistics, North America and the United States are facing a freshwater biodiversity crisis. In just the last one hundred years 123 freshwater animals have gone extinct in North America (Ricciardi and Rasmussen 1999). In the United States alone, 71% of freshwater mussels, 51% of freshwater crayfish and 37% of freshwater fish are currently considered vulnerable to extinction (Williams et al. 1993;

Warren and Burr 1994; Taylor et al. 1996; Master et al. 1998). Perhaps even more alarming are the predictions presented by Riccardi and Rasmussen (1999). Using extinction records and an exponential decay model they compared both current and predicted future extinction rates of several taxonomic groups by standardizing these rates according to the size of the species pool. From this analysis they found extinction rates of freshwater fauna in North America to be 5 times higher than those of terrestrial fauna. In addition, by assuming that imperiled freshwater species would not survive throughout the 21st century, their model projects a future extinction rate of 4% per decade, which is comparable to percentages that have been estimated for tropical rain forests.

While much attention has been focused on the global losses of terrestrial biodiversity especially in tropical ecosystems, comparatively little attention has been given to the alarming declines in freshwater biodiversity (Allendorf 1988; Hughes and Noss 1992; Allan and Flecker 1993; Stiassny 1996; Vreugdenhil et al. 2003). A variety of reasons have been given for this lack of scientific and public attention (See Winter and Hughes 1996), however, it is encouraging to see that within the last decade more and more attention has been focused on conserving freshwater biodiversity (Abell et al. 2000, Allan and Flecker 1993; Blockstein 1992; Hughes and Noss, 1992, Stiassny 1996; Ricciardi and Rasmussen 1999). Much of this attention has focused on outlining the severity of the problem, the likely causes for declines, and providing general recommendations for curbing losses of biodiversity in freshwater ecosystems. Yet, as Moyle and Yoshiyama (1994) noted, a critical first step to slowing these losses involves identifying gaps in existing efforts to conserve freshwater biodiversity across the landscape and then prioritizing opportunities to fill these gaps--and this is the overall goal of the USGS National Gap Analysis Program and our project.

The Gap Analysis Concept

The vast majority of past and present efforts to preserve biodiversity have primarily focused on rescuing individual species, subspecies, or populations from the brink of extinction or local extirpation (Franklin 1993; Scott et al. 1993). This reactive, species-by-species approach to conservation has proved difficult, expensive, biased, and inefficient (Hutto et al. 1987; Scott et al. 1987, 1991; Margules 1989; Noss 1991). Considering the limited human and financial resources dedicated to the recovery of the rapidly growing list endangered and threatened species it is unlikely that such approaches will slow the rapidly accelerating extinction rates we are currently witnessing (Scott et al. 1993; Wilcove 1993). The existing system of protected areas managed for their natural values represent about 10% of the world's surface area (Vreugdenhil et al. 2003) and only about 3% for the 48 conterminous United States (Scott et al. 1993), which is insufficient to maintain either species diversity or functional ecosystems (Grumbine 1990).

Biological diversity (biodiversity) is the concept around which new concerns about biological conservation are rallied. Biodiversity refers to the variety and variability among living organisms and the environments in which they occur and is recognized at genetic, population, species, community, ecosystem, and landscape levels of organization (U.S. Congress 1987, Noss 1990). The goal of biodiversity conservation is to reverse the processes of biotic impoverishment at each of these levels of organization. Ecological and evolutionary processes ultimately are as much a concern in a biodiversity conservation strategy as are species diversity and composition. Thus, biodiversity conservation represents a significant step beyond endangered species conservation (Noss 1991, Scott et al. 1991). Most significantly, biodiversity conservation is proactive as opposed to reactive last-ditch efforts.

Presuming that a relatively small portion of the total land base will be devoted to biodiversity conservation in the near future, objective techniques are needed to identify and rank proposed conservation areas. Of greatest interest is identification of species, community types, or representative ecosystems not already represented in areas managed exclusively or primarily for the long-term maintenance of populations of native species and natural ecosystem processes. Although a wide variety of conservation evaluation methods have been developed (see Usher 1986), only a few have attempted to assess the conservation value of large geographic areas in a quick and cost-effective manner (e.g., Bolton and Specht 1983, Margules and Austin 1991).

The US Geological Survey's National Gap Analysis Program (GAP) was initiated in 1988 to provide a coarse-filter approach for identifying biodiversity conservation needs. It seeks to identify gaps in existing conservation efforts that may be filled through establishment of new reserves or changes in land management practices (Scott et al. 1993). Gap Analysis is a technically efficient version of the well-established method of identifying gaps in the representation of biodiversity in biodiversity management areas (Scott et al. 1987, 1989, 1991; Burley 1988; Davis et al. 1990). This approach to conservation evaluation has been widely used in Australia (Specht 1975, Bolton and Specht 1983, Pressey and Nicholls 1991).

Goals and Objectives

The principal goal of our project was to identify riverine ecosystems and species not adequately represented (i.e., gaps) in the matrix of conservation lands in Missouri. In addition, we wanted to provide spatially explicit data that could be used by natural resource professionals, legislators, and the public to make more informed decisions for prioritizing opportunities to fill these conservation gaps and to devise strategic approaches for developing effective long-term biodiversity conservation plans. Furthermore, as a pilot project for a national program, we also had the goal of developing a broadly applicable gap analysis methodology. We addressed this goal by ensuring that we utilized nationally standardized and available geospatial data wherever possible and also by devising a flexible conservation assessment methodology, which can accommodate the differences in data availability (e.g., biological) that exists among states across the United States.

The specific objectives of the project were to:

1. Classify and map riverine ecosystems into distinct ecological units at multiple levels.
2. Develop statewide predictive distribution maps for all fish, mussel, and crayfish species at the valley-segment scale.
3. Generate local, upstream riparian, and overall watershed ownership/stewardship statistics for each valley segment.
4. Account for factors that negatively affect or threaten freshwater biodiversity in Missouri.
5. Assess gaps in the conservation of riverine ecosystems and species at multiple spatial scales.
6. Provide data and information to decision makers that will assist them with conservation planning efforts directed toward filling identified conservation gaps.

Study Area

Missouri is a physiographically diverse state situated in the east-central United States (Figure 1). This physiographic diversity can be generally described according the three Aquatic Subregions of the MoRAP aquatic ecological classification framework (See page 32 for an overview of the classification). The three subregions are remarkably different in their geologic, topographic, and edaphic features and these differences are reflected in the distributional relationships of their respective aquatic biota (Pflieger 1971).

Figure 1. Map of Missouri showing the major drainage systems and the three Aquatic Subregions that account for broad scale differences in instream habitat and freshwater assemblages across the state.

Central Plains

Boundary

The boundary of the Central Plains Aquatic Subregion (CP) includes all of the drainages entering the Missouri and Mississippi Rivers north of the Missouri River, excluding those smaller drainages of the Missouri River downstream (east) of the outlet of the Chariton River, but including the Blackwater-Lamine drainage. It also includes portions of the Osage River watershed—the Osage River subbasin above the confluence with the Sac River and the entire South Grand River watershed (see Figure 1).

Climate

The CP has a mean annual temperature of 53 ° F that ranges from 52 in the northwest to 54 in the southwestern and southeastern corners of the Subregion. Mean July maximum temperatures vary only slightly (88 to 90° F) and follow a northeast to southwest gradient. Mean January minimum temperatures range from 12 ° F in the northwest to 18 ° F in the southeastern part of the Subregion.

Mean annual precipitation ranges from 34 inches in the extreme northwest section of the Subregion to 41 inches in the southwest. Precipitation is lowest in the winter with monthly averages typically less than 2 inches during this period, which is notably less than the other two Subregions. Mean annual snowfall is highest in this Subregion with an overall average of 20 inches. Precipitation is generally highest from late spring to early fall with monthly averages of around 4 to 5 inches. Like the rest of the state, however, most parts of this Subregion experience a noticeable dip in precipitation during hottest part of the summer—late July and August, which can prove to be a very stressful period for riverine biota (Smale and Rabeni 1995b).

Intense rainfall, drought, and both heat and cold waves occur throughout Missouri and can all serve as potential disturbances affecting community composition over short and long temporal scales and also local and broad spatial scales. Once every two years 24-hour rainfall totals of 3 to 4 inches are expected to occur in any given part of the state and in north Missouri temperatures above 90° F are recorded on an average of 40-50 days each year (Nigh and Schroeder 2002).

Landform

Topography of this Subregion can be generally described as low or gently rolling plains (Pflieger 1989; Unklesbay and Vineyard 1992) (Figure 2). Streams occupy broad flat valleys that almost imperceptibly grade into the surrounding uplands (Pflieger 1989). Surface elevations range from approximately 600 feet in the floodplains of the larger streams draining to the Mississippi River to 1,200 feet in the northwest corner of the state. Elevations along the divides separating the larger rivers range from ~ 800 to 1,000 feet. The CP is gently sloping and moderately dissected, even within those areas affected by glaciation, with an overall average land slope of 5% and local relief of 80 feet, but relief typically ranges from 50 to 200 feet.

Figure 2. Hillshade map of Missouri, generated from a 30-meter Digital Elevation Model, illustrating the major differences in landform among the three Aquatic Subregions in the state.

Geology and Soils

Geology more than any other physiographic feature provides the distinction between the CP and Ozark Subregions (Figure 3). The distributional limit of many species characteristic of the Ozarks correspond with the Mississippian-age geologic formations that generally separate the younger Pennsylvanian formations that dominate the CP and the older Ordovician formations that dominate the central Ozarks (Pflieger 1971). Bedrock within the CP consists mainly of Pennsylvanian-age (3.2 million ybp) shales, coal, sandstones, and limestones with shales accounting for the greatest surface area (Unklesbay and Vineyard 1992; Nigh and Schroeder 2002). Along the Mississippi River, particularly in the North River and Salt River watersheds, there is a region known as the Lincoln Anticline or Fold, which brings older Mississippian and Ordovician-age formations to the surface (Nigh and Schroeder 2002). The distribution of many species characteristic of the Ozarks (e.g., southern redbelly dace and smallmouth bass) also extend into this narrow belt (Pflieger 1997).

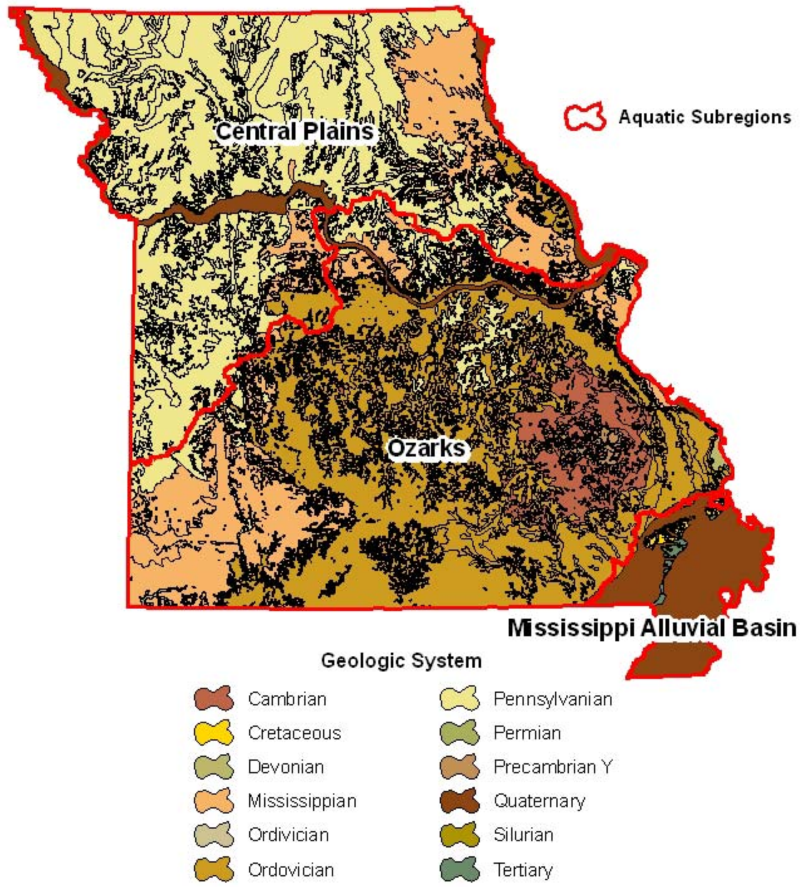

Figure 3. Map showing system-level geologic differences among the three Aquatic Subregions of Missouri.

As Nigh and Schroeder (2002) point out, the geography of soils in Missouri is quite complex as several contrasting soils can occur within a single hillslope sequence, yet broad regional patterns do exist. The CP is dominated by mollisols in the west/southwest and alfisols in the east/northeast. Although alfisols are generally thought to develop under forested conditions it is believed that both the mollisols and alfisols of this Subregion developed under prairie (Nigh and Schroeder 2002).

The original landscape of the Glaciated Plains subdivision was leveled by continental glaciation during the Pleistocene Epoch (2,000,000 ybp) and subsequently buried under layers of till and loess of varying thickness. Today this area north of the Missouri River consists of tills (sand, silt, and clays) that were largely derived from the disintegration of sandstones, limestones, and shales originating in Minnesota, Wisconsin, Iowa, Illinois, and northern Missouri (Hawker 1992). Loams and silty-loams with high to moderate infiltration rates are the dominant surface materials in much of this area. Highest infiltration rates occur along the loess bluffs bordering the Missouri and Mississippi Rivers. However, these relatively high infiltration rates are somewhat offset by the significantly steeper slopes of the loess bluffs, which promote runoff. The unglaciated Osage Plains is covered primarily by silty-clays and silty-clayey-loams with much slower infiltration rates. The Audrain Plain in the eastern part of the Subregion also has very slow infiltration rates and high runoff due to the presence of an extensive claypan in the subsoil, which is why this area is also sometimes referred to as the "Claypan" region.

Historic vegetation

Prairies dominated the CP prior to extensive Euro-American settlement. Prairies occurred as both upland prairies and wet prairies on the wide alluvial plains along the major rivers (Nigh and Schroeder 2002). Headwaters were likely marshy and dominated by wetland grass complexes while the immediate riparian area of many, but not all, of the larger streams was forested (Menzel et al. 1984; Rabeni 1996). In addition, oak forests occurred in the hills and blufflands along the Missouri and Mississippi Rivers, except in northwestern Missouri where midgrass prairies occupied the deep-loess blufflands (Nigh and Schroeder 2002). Upland deciduous forests also dominated the more rugged Lincoln Hills (Thom and Wilson 1980).

Flow Regime, Physical Habitat, Water Chemistry, and Energy Dynamics

The shales and heavy clay subsoils that underlie most of this Subregion are poor aquifers. As a result, there are relatively few springs and those that do exist have very minimal discharge and most are highly mineralized (Figure 4) (Pflieger 1971; Vineyard and Feder 1974). Despite this lack of springs, it is generally believed that prior to European settlement the marshy headwaters, coupled with the deep prairie sod, absorbed rainfall like a sponge and released it slowly to the stream channels providing continuous perennial flow throughout much of the system—except during the driest years (Menzel et. al 1984; Rabeni 1996). Prairies are now largely gone, replaced by crop fields and intensively grazed fescue pastures that facilitate runoff, soil erosion, and sedimentation (Pflieger 1997). These and many other land use changes have substantially altered hydrologic regimes—particularly high and low flow conditions.

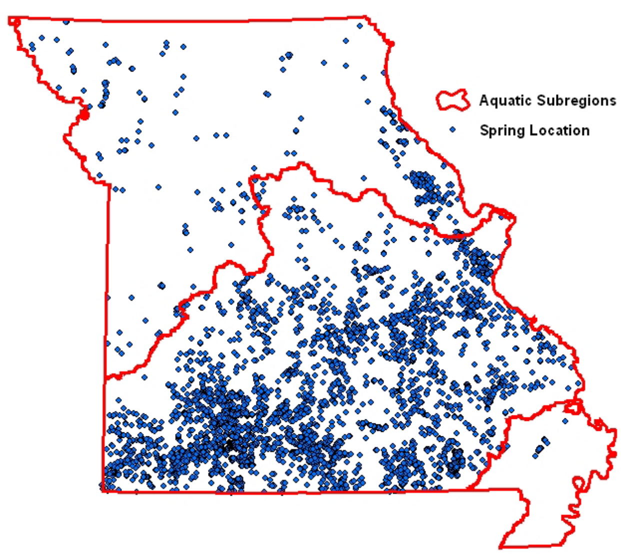

Figure 4. Map showing the distribution of springs in Missouri and the pronounce differences in the presence and density of springs among the three Aquatic Subregions.

Table 1 illustrates the present “flashy” nature and low-flow potential of streams within this Subregion. The ratio of the 10% to the 90% exceedence flows (10:90 ratio) is a commonly used measure of flow variability with higher numbers representing higher variability. The average 10:90 ratio for streams in the CP is 205 compared with only 15 for the Ozarks and 29 for the MAB (Table 1). Also, the 90% exceedence flow for the Lamine River at Otterville, MO is merely 7.7 cfs compared with 280 cfs for the similarly-sized North Fork River watershed at Tecumseh, MO, which is within the Ozark Subregion (Table 1). Collectively, the information provided in Table 1 reveals that streams in the CP; 1) are surface water dominated, 2) have widely fluctuating flow conditions, 3) have relatively high elevated and peak discharges, and 4) have extremely low base-flow discharges. The most surprising, and possibly the most ecologically relevant, fact from this table is that even the very large streams in this Subregion can become a mere trickle during extended dry periods.

Table 1. Hydrologic statistics for gaged streams representing each of the three Aquatic Subregions for Missouri. The 90% and 10% values represent the 90% and 10% exceedence flows (cfs) for each gage site, while peak values represent the highest instantaneous peak discharge. The 10:90 ratio is a measure of the “flashiness” of the hydrologic response.

Central Plains	**Gage Location**	**Area (mi²)**	**90%**	**10%**	**Peak**	**10:90 Ratio**
Fox River	Wayland	400	1.8	500	26400	278
S. Fabius River	Taylor	620	4.1	850	19700	207
Salt River	New London	2480	28	3900	107000	139
Cuivre River	Troy	903	4.8	1200	120000	250
Platte River	Agency	1760	20	2100	60800	105
Grand River	Gallatin	2250	24	2200	89800	92
Thompson River	Trenton	1670	29	2300	95000	79
Lamine River	Otterville	543	7.7	670	63700	87
Blackwater River	Blue Lick	1120	3.3	2000	54000	606
					Average	**205**
Ozark						
Big Piney River	Big Piney	560	120	1000	32700	8
Gasconade River	Rich Fountain	3180	500	6400	101000	13
Meramec River	Eureka	3788	500	5800	145000	12
St. Francis River	Patterson	956	50	2300	155000	46
N. Fork River	Tecumseh	570	280	1350	133000	5
Black River	Annapolis	484	120	1200	98500	10
Current River	Doniphan	2038	1200	4800	122000	4
Eleven Point River	Bardley	793	270	1500	49800	6
Spring River	Waco	1164	60	1850	151000	31
Elk River	Tiff City	872	85	1700	137000	20
					Average	**15**
MAB						
Little River	Morehouse	450	150	990	8250	7
LAnguille River	Palestine, AR	786	1175	10660	22803	9
Cache River	Egypt, AR	701	38	2740	8940	72
St. Francis River	Lake City, AR	2374	280	7500	42700	27
					Average	**29**

Water is normally a calcium-magnesium-bicarbonate type and total dissolved solids are generally less than 500 mg/l (VanDike 1995). Historically, within these relatively open upland prairie stream systems, autotrophic processes dominated and the energy to drive the system was supplied principally by algal production and secondarily by riparian grasses (Rabeni 1996). Farther downstream, forested bottomlands were more prevalent, and riparian shrubs and trees provided the dominant organic energy source. Presently, many streams are no longer nutrient limited, as both point and nonpoint pollution sources have significantly increased nitrate, phosphate, ammonia concentrations, particularly during elevated discharges (Jones et al. 1984; Perkins et al. 1998). In fact, nutrient concentrations within the CP are among the highest in the Midwest (Jones et al. 1984).

Low dissolved oxygen concentrations are quite common throughout this Subregion, especially during summer and winter (Pflieger 1971; Smale and Rabeni 1995b). To what extent agricultural practices have influenced the spatiotemporal prevalence and severity of hypoxic conditions is not known (Smale and Rabeni 1995b). Considering that many of the characteristic fish species of this Subregion are tolerant of hypoxic conditions suggests that such conditions occurred naturally and played a strong selective role in the evolution of this Subregions riverine fauna (Matthews 1987; Smale and Rabeni 1995a, 1995b).

Average channel gradients, in meters per kilometer, are 10.3 for headwaters, 2.3 for creeks, 0.7 for small rivers, and 0.3 for large rivers (Figure 5). These values are almost exactly intermediate between those of the other two Subregions—for every stream size class. Gradient differences between the three Subregions are most pronounced among headwater streams and become less pronounced as stream size increases. Historically, headwater streams had well defined pools and riffles and further downstream pools would become quite long and riffles were short, poorly developed, or often completely absent. Larger streams use to be extremely sinuous, which maintained high habitat diversity (diversity of depths, velocities and substrates). Silt, sand and fine gravel are the predominant bottom types. Bedrock is exposed only in some upland tributaries that have cut completely through the thick mantle of glacial till, and in some larger streams that transgress divides of the preglacial drainage. Streams within most of this Subregion are believed to have at one time carried much clearer and cooler water than they do today (Pflieger 1971; Rabeni 1996). Row-crop agriculture, grazing, channelization, roads, and removal of riparian vegetation have collectively led to substantially elevated sediment loads and temperatures in these streams. Even slight elevations in discharge will render these streams turbid due to resuspension of the abundant fine sediments that dominate the stream bottoms and banks. Only during extended base-flow conditions will most streams achieve any sort of clarity.

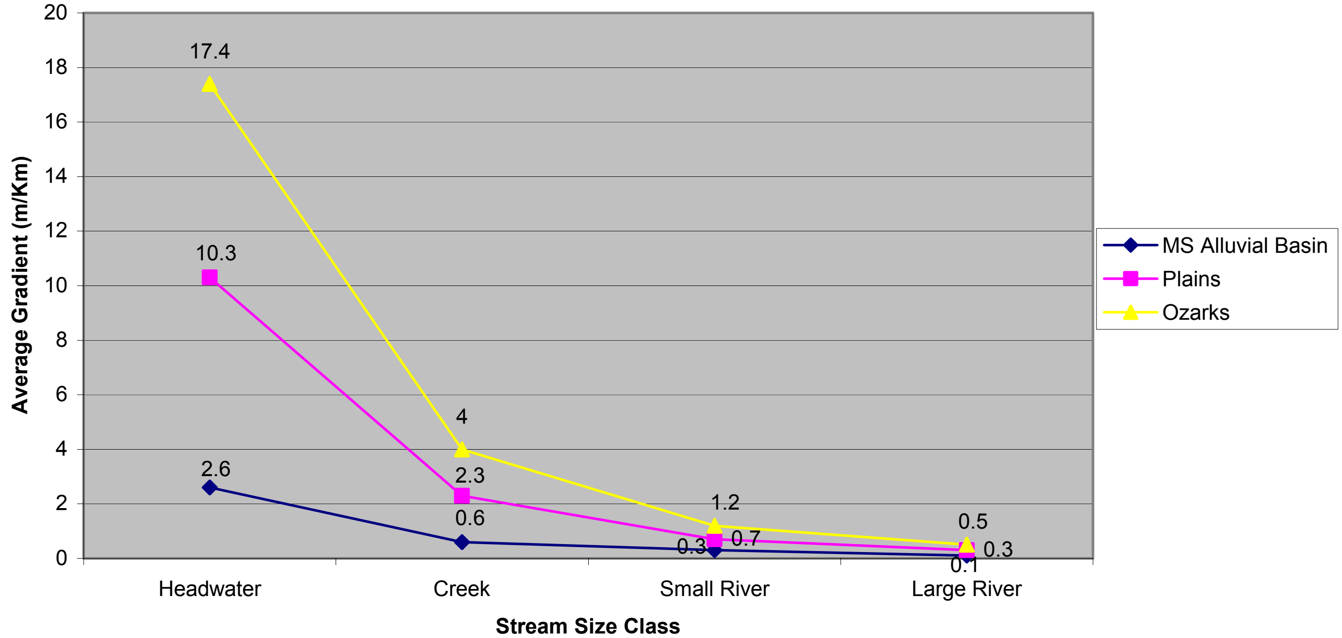

Figure 5. A comparison of the average stream gradients (m/km) for four stream size classes within each of Missouri's Aquatic Subregions.

Historically, the larger streams in this Subregion would freely meander across their broad-valleys and in the process create numerous backwater sloughs and oxbows. These lentic floodplain habitats served as important accumulators and tranformers of both autotrophic and heterotrophic energy sources, which the adjacent river and biota would access during overbank flows. They also served as important reproductive and nursery habitats for many fish species, as well as, the principle habitat for many crayfish, mussel, and amphibian species.

Presently there are very few channels, of any size, that have not been channelized or straightened to some degree. Almost all of the sloughs and oxbows have been drained and filled. These once diverse stream ecosystems have subsequently become remarkably homogenous in character; often straight as an arrow with uniform depths and velocities, and substrates dominated by sands and silts. Riffle habitats are not nearly as common as they historically were and woody structure has been, and continues to be, removed from most of the larger streams to further expedite the downstream transmission of water.

Large impoundments are not as prevalent as in the Ozark Subregion. Mark Twain, Thomashill, Long Branch, and Smithville reservoirs are the four major impoundments north of the Missouri River. South of the Missouri River the Harry S. Truman reservoir impounds the lower portions of the South Grand River and Tebo Creek. It has been estimated that approximately 300,000+ small artificial waterbodies (less than 2.5 acres) have been constructed in Missouri (Vandike 1995; Smith et al. 2002). The vast majority of these occur in the CP (Pflieger 1971; Nigh and Schroeder 2002). The ecological effects of these artificial waterbodies include the expansion of predatory game species (e.g., largemouth bass and bluegill) into entire regions or watersheds and more locally into headwater streams where they historically did not occur (Pflieger 1997), increased evaporation rates, diversion and delay of the downstream transmission of water, and altered biochemical reactions and groundwater interactions (Smith et al. 2002).

Biota

The CP Aquatic Subregion supports the second most diverse aquatic fauna in Missouri with a total of 190 species (141 fish, 42 mussels, and 7 crayfish). However, this number is somewhat misleading due to the large size of the CP and the fact that many species more characteristic of the Ozarks occur along the periphery of the CP. The local assemblage found in most streams of the CP is in most instances much lower than the other two Subregions. This occurs because CP streams are harsh environments for aquatic fauna with widely fluctuating environmental conditions and only species that can tolerate such conditions can persist (Pfliger 1997). Because the species that occur in the CP can live in a variety of environmental conditions they generally have much broader geographic ranges than species found in the other two Subregions (Pflieger 1997). Only two species, one fish (Topeka shiner: *Notropis topeka*) and one crayfish (grassland crayfis: *Procambarus gracilis*), are endemic to the CP.

The 138 fish species represent 25 different families. According to NatureServe's natural heritage database, two species are classified as globally threatened or endangered while fourteen are listed as state threatened or endangered. All but one of the native mussel species falls within the family Unionidae and one of three subfamilies, Ambleminae, Lampsilinae, and Anodontinae. The most common and widespread species are the giant floater (*Pyganodon grandis*), pondmussel (*Ligumia subrostrata*), fatmucket (*Lampsilis siliquoidea*), and paper pondshell (*Utterbackia imbecillis*). No mussel species are endemic to the CP. Three species are listed as globally threatened and seven are listed as state threatened or endangered. Only six crayfish species inhabit the streams of the CP Aquatic Subregion. The most common and widespread species are the virile crayfish (*Orconectes virilis*), papershell (*Orconectes immunis*), and grassland (*Procambarus gracilis*) crayfish. No crayfish species are listed as either global or state threatened or endangered.

Ozarks

Boundary

The Ozark Subregion includes all of the smaller direct tributaries to the Missouri River downstream from the outlet of the Little Chariton River, excluding the Blackwater/Lamine drainage (see Figure 1). It includes the eastern third of the Osage River watershed, downstream from, and including, the Sac River watershed, but excluding the South Grand River watershed. It also includes the entire Gasconade and Meramec River watersheds and those portions of the Neosho and White River watersheds that fall within Missouri. The southeast boundary with the MAB is marked by an abrupt change in elevation, relief, and surficial materials. This boundary affects streams like the Eleven Point, Current, Black, and St. Francis River that drain some of the most rugged and characteristic Ozark landscapes, but eventually flow into the MAB with a corresponding abrupt change in physicochemical conditions. The mainstems of these large rivers were clipped at this abrupt change in physiographic conditions and all of the tributaries (and their watersheds) that flowed into these mainstems while they were cutting through the Ozarks were included as part of the Ozark Subregion. Lastly, it includes all of the small direct tributaries to the Mississippi River between the outlet of the Headwater Diversion Channel near Cape Girardeau, Missouri and the outlet of the St. Francis River near Helena, Arkansas.

Three physiographic subdivisions of the Ozarks are widely recognized in Missouri: the St. Francois Mountains, the Salem Plateau, and the Springfield Plateau (Pflieger 1971; Jacobson and Primm 1997). The St. Francois Mountains is a small area of igneous knobs and peaks located in southeast Missouri, which covers much of the St. Francis River watershed and minor portions of the Black and Meramec River watersheds. The Salem Plateau is the largest subdivision and is coextensive with those areas of the Ozarks underlain by Ordovician age and older sedimentary rocks. The Springfield Plateau lies west of the Salem Plateau and is coextensive with those areas underlain by Mississippian age rocks. Our discussion of variations in physiographic character and stream conditions will often be framed within these three subdivisions.

Climate

The Ozark Subregion has a mean annual temperature of 55 ° F and ranges from 54 in the north to 56 in the southeastern corners of the Subregion. Mean July maximum temperatures are a fairly uniform 90° F, however, slightly lower maximums occur in the central Ozarks. Mean January minimum temperatures range from 16 ° F in the northeast to 22° F in the southeastern part of the Subregion.

Mean annual precipitation ranges from 40 inches in the north to 48 inches in the southeast. Precipitation is lowest in the winter with monthly averages around 2 to 3 inches during this period. Estimated mean annual evapotranspiration is 30 to 35 inches/year. Precipitation is generally acidic with a low dissolved solids concentration (Adamski et al. 1995). There is a wide range of mean annual snowfall across the Subregion, but it is still a hydrologically insignificant form of precipitation (Tryon 1980). In the northeast snowfall averages 20 inches, but only half this amount generally falls in the southeast corner. Precipitation is generally highest from late spring to early fall with monthly averages of around 3 to 5 inches but, like the Central Plains Subregion, there is a noticeable dip in precipitation during hottest part of the summer; late July and August.

Landform

Topography of the Ozark Subregion is highly variable ranging from very steep in those areas bordering the major streams to nearly level along many of the drainage divides (Thom and Wilson 1980) (see Figure 2). Valleys in the upper parts of basins are generally wide with gradual slopes extending from the stream channel to the valley wall (Jacobson and Primm 1997). Larger streams occupy narrow, steep-sided, valleys that are frequently bordered by high bluffs (Pflieger 1989). Surface elevations range from approximately 400 feet in the floodplains of the larger streams draining to the Mississippi River to almost 1,800 feet at Tom Sauk Mountain—the highest elevation in Missouri. Elevations along the divides separating the major drainages typically range from 1200 to 1,600 feet in the central Ozarks.

The Subregion is moderately sloping and highly dissected with an overall average land slope of 9% and local relief of 148 feet, however local relief of 300 feet or more is common (Thom and Wilson 1980). Slopes greater than 20% are most common in the St. Francois Mountains and the Salem Plateau, particularly in those lands bordering the major rivers. The Springfield Plateau has much lower slopes and local relief, which are comparable to those found in northwestern Missouri.

Geology and Soils

Geologically, the Ozarks is one of the oldest regions of the world, having been an exposed, unglaciated, land surface since the end of the Paleozoic Era (Steyermark 1959). The Subregion is characterized by a core of Precambrian igneous rocks that underlie the St. Francois Mountains surrounded by nearly flat-lying Paleozoic sedimentary rocks of Cambrian, Ordovician, and Mississippian age (Jacobson and Primm 1997) (see Figure 3). Ordovician age rocks are the dominant underlying structure within the Salem Plateau. The Springfield Plateau is primarily underlain with Mississippian and Pennsylvanian age rocks, which also underlie the northern edge of the Ozarks along the Missouri River. As previously stated, the distributional limit of many species characteristic of the Ozarks correspond with the Mississippian-age geologic formations that separate the younger Pennsylvanian formations that dominate the Central Plains from the older Ordovician formations that dominate the central Ozarks (Pflieger 1971). The sedimentary rocks of this Subregion are dominated by cherty limestone and dolomite, with smaller contributions of sandstone and shale (Jacobson and Primm 1997).

The alfisols and ultisols that dominate the Ozarks are generally considered “poor” and are unsuited for row-crop agriculture except within the alluvial flooplains along the larger rivers and some of the broad flat ridgetops. Weathering of the carbonate rocks has produced a variable thickness of residuum. On areas of low slope and chert-rich rocks, clay- and gravel-rich residuum and colluvium can accumulate to as much as 6 or 7 meters thick (Jacobson and Primm 1997). Steeper slopes have thin, clay-rich soils, or no soil at all. Most soils fall within the NRCS Hydrologic Soil Groups B or C (i.e., moderate to slow infiltration rates) (See Figure 7) and have high potential to leech nutrients to groundwater and a high potential for runoff during periods of intense rainfall that bypass the karst drainage system (Jacobson and Primm 1997; Adamski et al. 1995). In areas of high relief and steep slopes the surface texture of soils range from coarse-loam to very coarse-silty-loam. Gradual sloping areas are dominated by silty-loams. Extremely stony soils occur in the St. Francois Mountains and also in those lands just north of the Missouri River between the outlet of the Osage River and the city of St. Louis.

Historic vegetation

Presettlement vegetation included forests, woodland, savanna, and significant prairie tracts (Nigh and Schroeder 2002). Forests covered most of the Salem Plateau and St. Francois Mountains. Oaks dominated most of the forests, however, pine was codominant and sometimes occurred as nearly pure stands in the southern and southeastern sections of the Subregion (Nigh and Schroeder 2002). Bottomlands were typically covered in deciduous forest. These lowland forests generally contained a larger variety of species including sycamore, cottonwood, maple, black walnut, butternut, hackberry, popular, and bur oaks (Adamski et al. 1995). Prairies occurred in small to moderately sized tracts along the outer belts of the Ozarks and were most abundant within the Springfield Plateau. These prairies generally occurred on the smooth uplands while the bottomlands were forested (Sauer 1920). These scattered upland prairies along the northern and western border of the Ozarks represented a transitional vegetative cover between the forested interior of the Ozark Subregion and the more extensive prairie tracts of the Central Plains Subregion.

Flow Regime, Physical Habitat, Water Chemistry, and Energy Dynamics

Within the soluble carbonate rocks (i.e., limestone and dolomite) that dominate the Ozarks a karst drainage system has developed with abundant caves, sinkholes, springs, and underground streams (Vineyard and Feder 1974; Adamski et al. 1995). This karst topography creates significant interactions between surface and groundwater (Petersen et al. 1998). Losing streams, which are scattered throughout the Subregion, are one example of this interaction. Losing streams lose a portion or all of their flow to the underlying groundwater system. Even fairly large streams like the aptly named Dry Fork, that have surface flow during base flow in their upper reaches, become completely dry for considerably long stretches only to regain surface flow further downstream.

As previously mentioned, the average 10:90 ratio for selected Ozark streams is only 15 (see Table 1). This low number indicates the general stability and high baseflow potential of Ozark streams. These high base flows are the result of relatively high groundwater inputs from conduit or diffuse springs, which are extremely abundant throughout the Ozarks, especially within the Salem Plateau (see Figure 4). Highest spring densities occur within the White River drainage, while the highest concentration of large springs occurs within the Gasconade and Current River drainages, particularly within the Ozark National Scenic Riverways. These large springs have enormous underground contributing areas and some have flows as large as small rivers (Vineyard and Feder 1974; Pflieger 1989). Streams that receive water from a large spring may maintain water temperatures suitable for supporting coldwater fisheries for a considerable distance below the spring (Pflieger 1975). Sections of several Ozark streams are classified as coldwater and all but a few contain naturalized populations of rainbow trout or put and take fisheries of brown and rainbow trout.

On a per unit area basis (unit discharge), peak discharges in Ozark streams are often considerably larger than the other two Subregions. The shallow soils coupled with the steep terrain can produce tremendous surface runoff during intense rainfall events that bypass the karst drainage system. Average unit discharge for peak flows recorded at selected gage stations on Ozark streams is 120 cfs per square mile, compared with 63 in the CP and only 20 in the MAB (see Table 1). Highest unit discharges occur in the St. Francis, Elk, Spring, and Black River watersheds, which have lower spring densities and fewer large springs than the other Ozark watersheds included in Table 1. Consequently, despite the relatively high baseflow discharge of Ozark streams, surface runoff from intense storms can produce amazingly high unit discharges and it is quite common to find woody debris left behind from flooding as high up as 15 to 20 feet within the surrounding riparian vegetation (S. Sowa, personal observation).

Many natural factors affect water quality in the Ozarks including climate, physiography, geology, and soils. These factors are particularly influential to stream water quality during periods of low flow when the percent of ground-water contribution is high (Adamski et al. 1995). The Springfield and Salem Plateaus have very similar water quality, but dissolved solids and alkalinity are lower in the Springfield Plateau. Waters in the Springfield Plateau are calcium bicarbonate, whereas Salem Plateau waters are calcium magnesium bicarbonate due to the greater prevalence of dolomite bedrock. The St. Francois Mountains waters are also calcium magnesium bicarbonate, but are less mineralized than many other waters in the Subregion due to the prevalence of resistant igneous rocks (Adamski et al. 1995). As a whole, Ozark streams are quite clear and even on most of the larger streams one can easily see the bottom of the deepest pools during baseflow.

Nutrient concentrations in streams with largely forested watersheds are some of the lowest in the Nation while concentrations in streams draining other land uses (e.g., urban and cropland) are some of the highest in the Nation (Jones et al. 1984; Petersen et al. 1998). Pesticide and other organic compound concentrations are generally low, while concentrations of semivolatile organic compounds in bed sediments downstream from urban areas are some of the highest in the Nation (Brookshire 1997; Petersen et al. 1998). Trace element concentrations in lead and zinc mining areas of the Ozarks are also higher than many other regions of the country.

Low dissolved oxygen concentrations are generally not a problem in Ozark streams (Brookshire 1997). However, low concentrations can and do occur within the intermittent pools of headwater streams from late summer through winter due to high temperatures and high biological oxygen demand resulting from the decay of organic matter trapped within these pools (Matthews 1998). Low dissolved oxygen concentrations also occur below some of the large impoundments within the Subregion. These coolwater Ozark streams and their associated aquatic assemblages are susceptible to elevated temperatures (Sowa 1993; Smale and Rabeni 1995b). Removal or thinning of riparian vegetation is a common practice in the Ozarks (Jacobson and Pugh 1997). This activity not only increases the amount of solar radiation reaching the stream surface, but also results in wider and shallower channels (Fajen 1981). This widening and reduction in depth increases the surface area per unit volume of water, which leads to further increases in solar radiation inputs per unit length of stream.

Headwaters generally have shallow valleys and steep gradients averaging 17.4 m/Km but ranging as high as 40 or 50 m/Km (see Figure 5). Stream reaches are characterized by short pools and well-defined riffles with substrates comprised of gravel, cobble, boulder and bedrock. Small springs and seeps are common especially within the south and southeastern Ozarks. Many headwater streams have intermittent flow, meaning they may be dry with the exception of the deepest pools during the summer (Pflieger 1989). Creeks have deeper valleys and significantly lower gradients that the headwaters—averaging 4 m/Km (see Figure 5). Riffle substrates are generally gravel and cobble while the substrate in pools will include detritus, sand, and silt in addition to coarser substrates. Gravel bars on convex banks are common as are extensive stretches of exposed bedrock, especially when the channel is near the valley wall (S. Sowa, unpublished data). As with headwater streams all except the largest and deepest pools may be dry during the summer.

Valleys of small rivers are characteristically narrow and steep sided (Jacobson and Primm 1997). These valleys are frequently entrenched from downcutting during past periods of uplift and may be up to 300-500 feet deep (Fenneman 1938). Limestone bluffs as high as 150 feet border these streams in many places and pools adjacent to these bluffs (i.e., bluff pools) are often extremely deep and contain large complexes of boulders. These bluff pools have been identified as important overwintering habitat for many species and are also a key habitat for the spectaclecase mussel (*Cumberlandia monodonta*) (Peterson 1996; Baird 2000). Gradients average 1.2 m/Km which is only slightly higher than the other two Subregions (see Figure 5). These small rivers exhibit deep pools with sand and silt bottoms, but riffles still contain mainly gravel and cobble substrates. Large springs are fairly common along these smaller mainstem streams, which typically have permanent flow. Large rivers have wide deep valleys and with an average gradient of 0.5 m/Km (see Figure 5). Long pools and deep chutes along with backwaters and cut-offs typify these largest Ozark rivers. Pools have sand and silt bottoms, while swifter areas maintain gravel and cobble substrates, except for those streams directly entering the Missouri or Mississippi Rivers (e.g., Meramec and Gasconade Rivers). The substrates near the outlets of these rivers are almost entirely comprised of fine sediments due to backwater effects that occur during floods on the two great rivers. Backwater flooding is a phenomenon in which high water stages on the Missouri and Mississippi Rivers create a damming effect, preventing tributary drainage into the mainstem and at times even reversing tributary flow (Brown et al. 1999). This situation results in long-duration flooding accompanied by the deposition of fine sediments and nutrients throughout the lower ends of these tributaries, up to where the elevation on the tributary channel equals the elevation of the floodwaters on these great rivers.

Under natural conditions, the energy dynamics of Ozark streams nearly typify the synthesis put forth in the River Continuum Concept (Vannote et al. 1980). Headwaters and creeks are generally well shaded with little primary production and are heterotrophic—deriving most of their energy from allocthonous inputs from the surrounding riparian vegetation. The invertebrate community within these headwaters is dominated by shredders which breakdown the abundant coarse particulate organic matter. In small rivers the channels become wider and primary production increases such that photosynthesis is greater than respiration resulting in an autotrophic community. In these reaches there is a codominance of collector-filterers and scrapers, which feed on the attached algae. In large rivers (orders >6), the surrounding vegetation does not shade the stream, however, turbidity of the water inhibits primary production and even though the vegetation contributes little to the energy budget of the system, these reaches are also characterized as heterotrophic. However, some large rivers in the Ozarks (e.g., Current, Black, Meramec) maintain relatively clear waters and therefore maintain relatively high autotrophic production.

Biota

The Ozark Aquatic Subregion supports a highly diverse and distinctive aquatic fauna. A total of 296 species (202 fish, 65 mussels, and 29 crayfish) can be found in the flowing waters of this Subregion. Fifty-six of these species (25 fish, 9 mussels, and 18 crayfish), or 19%, have geographic ranges that are either entirely or nearly restricted to the Subregion. This high number of endemic species is a result of both the age of the Ozarks and the isolation of the principal drainage systems by the Great Rivers (e.g., Missouri and Mississippi Rivers) into which they drain (Pflieger 1971).

The 202 fish species represent 27 different families with the most dominant small fishes being minnows (Cyprinidae) and darters (Percidae) while suckers (Catastomidae) and sunfishes (Centrarchidae) are the dominant large species. Twenty six of these fish species are considered endemic to the Ozark Aquatic Subregion. According to NatureServe's natural heritage database, 6 species are classified as globally threatened or endangered while 32 are listed as state threatened or endangered.

There are 63 native and two introduced mussel species in the Ozark Aquatic Subregion. All but one of the native species falls within the family Unionidae and one of three subfamilies, Ambleminae, Lampsilinae, and Anodontinae. The spectaclecase (*Cumberlandia monodonta*) is the only mussel species from the family Margaritiferidae in Missouri. The most common and widespread species are the giant floater (*Pyganodon grandis*), pondmussel (*Ligumia subrostrata*), fatmucket (*Lampsilis siliquoidea*), and paper pondshell (*Utterbackia imbecillis*). Nine mussel species have geographic ranges that are either entirely or nearly restricted to the Ozarks. Eleven species or subspecies are listed as globally threatened or endangered and twenty, or nearly 30%, are listed as state threatened or endangered.

Like all species of crayfish east of the Rocky Mountains, all of 29 crayfish species that inhabit Ozark streams fall within the family Cambaridae (Pflieger 1996). The most common and widespread species are the spothanded (*Orconectes punctimanus*), golden (*Orconectes luteus*), devil (*Cambarus diogenes*), and virile (*Orconectes virilis*) crayfish. Nearly three quarters (21 species, 72%) of the crayfish species found in Ozark streams are endemic to the Ozark Aquatic Subregion. Seven of these species are listed as globally threatened and 7 are listed as either state threatened or endangered.

Mississippi Alluvial Basin (MAB)

Boundary

The MAB includes the lower portions of the Current, Black, and St. Francis River watersheds. It also includes the Little River drainage, St. Johns Ditch and the New Madrid Floodway of the Mississippi River (see Figure 1). The Benton Hills and Crowley's Ridge, which are essentially topographic "islands" of Ozark character surrounded by a "sea" of nearly flat alluvial plain are also included within the MAB Subregion. The features defining the boundary between the MAB and the Ozarks is described above within the discussion of the boundary of the Ozark Subregion.

Climate

The MAB has the highest mean annual temperature and precipitation within the state. The mean annual temperature is 58 ° F and ranges from 57 in the north to nearly 59 in the south. Mean July maximum temperature is 90° F, which is essentially the same as the Ozarks, however, mean January minimum temperature is 24° F, which is slightly higher than the Ozarks and substantially higher than the Central Plains.

Mean annual precipitation is 50 inches. Unlike the other two Subregions, which generally receive the lowest amounts of precipitation during winter, precipitation in the MAB is lowest in late summer and early fall. There are generally two peaks in precipitation, one throughout the spring and again in late fall and early winter with monthly averages of around 5 inches during these two periods. Like the rest of the state, rainwater is generally acidic with a low dissolved solids concentration. On average this Subregion only receives 6 to 8 inches of snowfall each year.

Landform

The Mississippi River and its tributaries originally sculpted the MAB landscape producing a surface geomorphology consisting of natural levees, meander scar lakes, point bars, ridges, and swales (Brown et al. 1999). More generally this Subregion is characterized as a broad plain that averages 300 feet above sea level with a gentle slope to the south (see Figure 2). The overall average slope is less than 1% and overall average relief is approximately 10 feet. Crowley's Ridge, which rises anywhere from 50 to 250 feet above the surrounding plain, is the most prominent topographic feature of the Subregion. This topographic island has much higher slopes of approximately 5% and local relief ranging to 150 feet or slightly more in some places.

Geology and Soils

Bedrock is an unimportant feature of MAB landscape except within Crowley's Ridge, which is underlain mainly by Cretaceous and Tertiary sandstones, siltstones and shales with some minor inclusions of Ordovician sandstones and dolomites (see Figure 3). Crowley's Ridge is capped by a relatively thick mantle of windblown loess deposits similar to those found along the bluffs of the Missouri and Mississippi Rivers in other parts of the state (Pflieger 1971). The remainder of the MAB is underlain by Cretaceous and Tertiary deposits of clay, sand, and gravel that range from a few feet to more than 2,700 feet in thickness (Grohskopf 1955). These older sediments are buried under a layer of alluvium deposited by the St. Francis, Mississippi, and Ohio rivers during Pleistocene and recent times (Pflieger 1971). Inceptisols and entisols with relatively low infiltration capacities dominate the alluvial bottoms of the larger rivers and ditches while higher ground is covered primarily by alfisols with moderate to high infiltration capacities (Nigh and Schroeder 2002).

Historic vegetation

In its original condition the MAB was one of the most heavily timbered regions of Missouri (Pflieger 1971). Also, despite the nearly level landscape of this Subregion, a relatively high water table combined with varied soils provided a diverse landscape for plant communities to form. Site conditions within the MAB ranged from permanently flooded areas supporting only emergent or floating aquatic vegetation, to high elevation sites supporting complex hardwood forests (Brown et al. 1999). The dominant historic natural communities included various types of bottomland hardwood forests, but major areas consisted of upland deciduous forests dominated by oaks and smaller areas associated with sandy ridges supported prairie and oak savanna (Nigh and Schroeder 2002). The distribution of community types and successional stages of the bottomland hardwood forests was partly determined by the timing, frequency, and duration of flooding (Brown et al. 1999). Elevational differences of only a few inches resulted in great differences in soil saturation characteristics and plant distribution. As a result, components of this bottomland hardwood ecosystem ranged from bald cypress/tupelo swamp communities in saturated or inundated situations, to a cherrybark oak/pecan community where inundation is infrequent and temporary (Brown et al. 1999). Between these distinct types are transitional overcup oak/water hickory, elm/ash/hackberry, and sweetgum/red oak communities.

Of all the regions of Missouri, the MAB has lost the greatest part of its historic vegetation with only a few small remnants of the nineteenth century forest cover remaining (Nigh and Schroeder 2002). Almost 95% (excluding Crowley's Ridge) of this Subregion has been drained and converted to farmland with the vast majority being cropland; particularly soybeans, wheat, corn, cotton, and rice. The only extensive areas of standing timber and swamps that remain are Duck Creek Conservation Area and Mingo National Wildlife Refuge. Other smaller remnants include Otter Slough, Alldred Lake, Wolf Bayou, Big Oak Tree State Park, and Cash Swamp.

Flow Regime, Physical Habitat, Water Chemistry, and Energy Dynamics

The MAB is now a region of few natural alluvial rivers as a result of one of the world's most ambitious land clearing and drainage efforts that took place during the first half of the twentieth century. This once swamp- and wetland-dominated landscape is now covered with thousands of miles of an amazingly complex network of drainage ditches. Channelization efforts typically lead to a reduction in overall stream miles, however, in the MAB ditching and draining efforts have led to a dramatic increase in the mileage of stream channels. The actual increase in miles of channel is unknown, however, historic maps of the Subregion show very few stream channels—certainly nothing close to what exists today.

Average annual runoff ranges from 18 to 20 inches, which is the highest in the state. However, the nearly flat topography of the MAB results in low runoff rates and the sand and gravel alluvial deposits that overlay the relatively impermeable clayey subsoils make excellent shallow aquifers (Pflieger 1971). These two factors are collectively responsible for the relatively stable hydrographs and high baseflow potential of streams and ditches within the MAB where even the smallest channels tend to carry water during the driest periods of the year. Data from four long-term USGS gaging stations in Table 1 (1 from MO, 3 from AR) illustrate the influence of shallow alluvial aquifers on the hydrologic regimes of streams and ditches that drain this highly altered landscape. The average 10:90 ratio for these four rivers is just 29 and the unit discharges for 90% exceedence flows range from 0.12 to 1.5 cfs per square mile (see Table 1). Values for these measures of flow stability and baseflow potential are much more similar to streams within the Ozarks than those in the Central Plains. Also, the average of the unit discharges for peak flows in the MAB is merely 20 cfs per square mile which is considerably lower than averages for the Central Plains (63) and the Ozarks (120) and depicts the relatively low rates of surface runoff for this Subregion even during periods of intense rainfall (see Table 1).

Basic water chemistry in the MAB is similar to streams draining the Salem Plateau within the Ozarks. Waters are principally calcium magnesium bicarbonate and exhibit dissolved concentrations between 140 and 170 mg/L (Adamski et al. 1995). As part of the USGS National Water Quality Assessment (NAWQA) program, Kleiss et al. (2000) conducted a water quality assessment of the Mississippi Embayment, which largely corresponds with the boundaries MAB. Their study found herbicide and pesticide concentrations to be relatively high in the ditches and streams draining this Subregion. Insecticide concentrations were also fairly high near urban areas. Nitrogen concentrations were generally in the middle of the range of national data, whereas phosphorous concentrations were in the 67th to 93rd percentile of other study units examined across the Nation. Nutrients entering the mainstem generally cause few water quality problems because of buffering and dilution (Boone 2001). Enrichment in many of the smaller ditches, however, can cause extreme turbidities, excessive growth of aquatic plants, and low dissolved oxygen concentrations, which can cause localized fish kills during summer low flow periods (MDNR 1984). The organochlorine insecticide DDT, or one of its metabolites, was found in every fish tissue sample, 67% of the streambed-sediment samples, but only 14% of the surface-water samples. Unlike surface waters, groundwater quality was generally quite good. This is likely the result of the thick confining layers of clay within this Subregion, which generally isolate the groundwater from surface activities (Kleiss et al. 2000).

Despite the seemingly homogenous character of the MAB landscape, the ditches and few remaining natural streams in the Subregion vary substantially in terms of discharge, turbidity, current, substrates, aquatic vegetation and shading by riparian vegetation (Pflieger 1971). Smaller ditches are most variable in character, but generally have higher water clarity than larger ditches. Some have no perceptible current during base flow with bottoms comprised mainly of silt while others are fairly swift and have bottoms mostly comprised of sand and small gravel (Pflieger 1989). Channels with clear water and little riparian shading are generally choked with submergent vegetation. Some of the major ditches are large enough to be classified as either small or large rivers. These ditches are extremely wide and shallow with considerable current throughout. Channel gradients are significantly lower in the MAB than the other two Subregions (see Figure 5). Channels classified as headwaters have an overall average gradient of 2.6 m/Km, while the average gradient of channels falling within all other sizes classes are less, and often substantially less, than 1 m/Km. Despite these low stream gradients headcutting and rill and gully erosion are substantial problems upstream from channelized sections (Boone 2001). Cover is generally sparse and is often confined to undercut banks and associated vegetation or woody debris. Woody cover is typically much more abundant in unchannelized stream sections (Boone 2001).

The small streams draining Crowley's Ridge have hydrologic and instream habitat conditions similar to those found in some streams within the Ozarks. Streams are relatively clear with sand and gravel substrates and occasional bedrock exposures. Seeps and springs are common and many of the smallest channels are either intermittent or completely dry during base flow periods.

Biota

The aquatic fauna of the MAB Subregion is not nearly as diverse as the Ozarks, but no less distinctive (Pflieger 1996; 1997). A total of 172 species (128 fish, 34 mussels, and 10 crayfish) inhabit the streams and ditches of this Subregion. While only five of these species are endemic to the MAB, thirty species of fish and crayfish are either confined or occur only occasionally elsewhere in Missouri. Many of these species are characteristic of the Gulf Coastal Plain of the southern United States and reach the northern limit of their range in MAB Subergion of southeast Missouri (Pflieger 1996; 1997).

The 128 fish species represent 23 different families with the most dominant small fishes being minnows (Cyprinidae) and darters (Percidae). There is really no single group of large fishes that are dominant in the MAB (Pflieger 1996). Only two of these fish species, the bantam sunfish (*Lepomis symmetricus*) and the sabine shiner (*Notropis sabinae*), are endemic to the MAB. One species, the pallid sturgeon (*Scaphirhynchus *albus*), is classified as globally endangered while 23 are listed as state threatened or endangered. All of the 34 mussel species of the MAB fall within the family Unionidae and one of three subfamilies, Ambleminae, Lampsilinae, and Anodontinae. No mussel species are endemic to the MAB and the western fanshell (*Cyprogenia aberti*) is the only globally listed species (threatened) by NatureServe's natural heritage network. Five species are listed as state threatened or endangered.

The MAB supports a small but distinctive crayfish fauna of 10 species (Pflieger 1996). The genera Orconectes and Cambarus, which dominate the Ozark fauna, are represented by only two and one species, respectively in the MAB. There are three species of Procambarus, two species of Cambarellus, and one species each of Fallicambarus and Faxonella (Pflieger 1996). The most common and widespread species are the devil (*Cambarus diogenes*), gray-speckled (*Orconectes palmeri*), red swamp (*Procambarus clarkii*), and Shufeldt's dwarf (*Cambarellus shufeldtii*) crayfish. Only the shrimp (*Orconectes lancifer*) and vernal (*Procambarus viaeviridis*) crayfish are endemic to the MAB. No species are listed as globally threatened or endangered while the digger (*Fallicambarus fodiens*), shrimp, and shield (*Faxonella clypeata*) crayfish are state listed as threatened.

Focus of the Missouri Pilot Project

The above objectives are by no means small objectives. Consequently, we had to establish some priorities to make the project more reasonable in scope and to help maintain a more structured approach to our efforts. First, as evidenced by information in the preceding sections and our project objectives, we strictly focused on riverine environments, exclusive of the Missouri and Mississippi Rivers. Missouri is essentially a "stream state" and most of our aquatic biodiversity concerns are centered in riverine ecosystems (Pflieger 1989). Second, although it is envisioned that the aquatic component of GAP will ultimately entail holistic assessments for all major aquatic taxa, our project focused on *fish, mussels, and crayfish*. Explicitly focusing on these three taxa was a result of the availability and quality of existing collection data.

Why the aquatic and terrestrial components cannot be integrated a priori

The title of this section is by far the most common question asked of those of us working on aquatic GAP projects. This is certainly an important question, because ideally conservationists would like to believe that all elements of biodiversity should ultimately be integrated into a single assessment of conservation gaps and opportunities. We admit that we had these same aspirations when we began our project and held this belief for a very long time. However, we began to realize that even though the basic goal and objectives of the terrestrial and aquatic components of gap are indeed the same, there is a major obstacle to such upfront integration.

The foremost obstacle to a fully integrated terrestrial and aquatic gap analysis pertains to the fact that if we are going to conserve biodiversity we must conserve ecosystems (Franklin 1993; Grumbine 1994). Traditionally, ecoregions have served as the geographic framework for defining terrestrial ecosystems and conserving terrestrial biodiversity. While ecoregions do a good job of accounting for structural and functional differences in freshwater ecosystems, they do not account for important compositional differences (species and genetic composition) resulting from isolation of freshwater faunas largely related to historical and contemporary drainage patterns (Figure 6) (Pflieger 1971; Matthews 1998). Also, in most instances, ecoregions do not define interacting systems, which is a fundamental concept found in virtually every definition of an ecosystem. Watersheds, on the other hand, do define interacting systems and do act as a principle evolutionary and distributional constraint for freshwater organisms. Major drainage systems are analogous to islands embedded within the landscape. Consequently, defining ecosystems in freshwater environments requires the integration of ecoregion and drainage boundaries. Ironically, in most instances watershed boundaries play only a marginal role in the defining interactive systems for terrestrial environments, except in mountainous regions. This dichotomy is a critical fundamental difference that dictates the use of different geographic frameworks for conserving freshwater and terrestrial biodiversity. This is why we developed a separate aquatic ecological classification framework for our project. This fundamental difference should not be viewed as an impediment to conserving biodiversity. We like to say that we have “geography on our side.” Meaning, separate conservation assessments or gap analyses can be performed and the results then integrated a posteriori into an overall assessment or analysis.

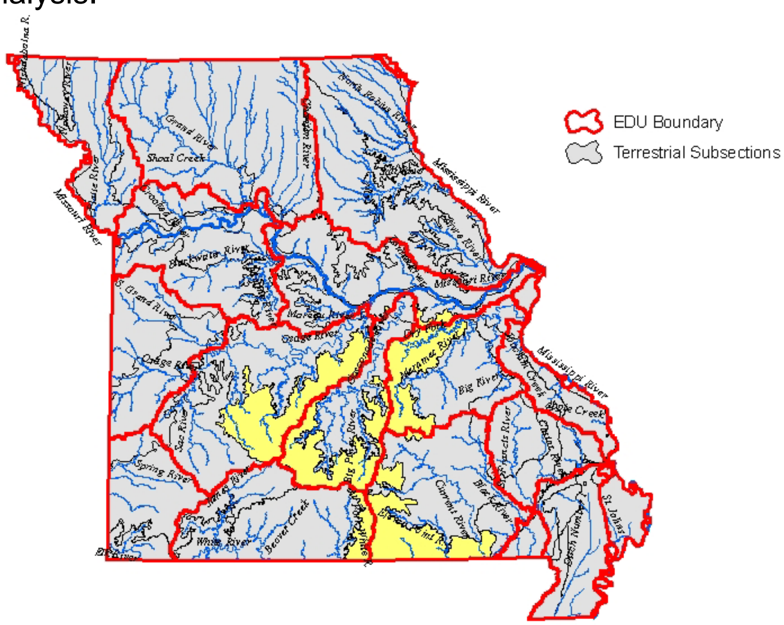

Figure 6. Map showing how terrestrial ecoregions do not account for important evolutionary constraints that partially determine local assemblage composition. The Ozark/Central Plateau ecological subsection (in yellow) crosses five major drainages (EDUs) within Missouri. Even though the physicochemical character of the streams across the Ozark/Central Plateau are relatively similar, the local assemblages that inhabit the streams within this ecological subsection differ across the major drainages due to the different evolutionary histories of these drainages.

An Overview of Biodiversity Conservation Planning

Before discussing the specific data we compiled or developed for the Missouri Aquatic GAP Project, we believe it necessary to provide an overview of conservation planning. This overview will provide a general context that will more clearly illustrate why we developed each geospatial datalayer. Margules and Pressey (2000) and Groves (2003) both provide excellent overviews of conservation planning and we essentially cover the most basic elements discussed by these authors in our review of the topic.

The first step in conservation planning is to establish a goal expressing the focus of the effort. This should not be confused with the quantitative conservation goals that are established when devising a specific conservation strategy (see below). Goals pertaining to biodiversity conservation have been variously described, but all have in common the conservation and restoration of the processes that generate or sustain biodiversity.

Once a goal has been established, the fundamental principles, theories, and assumptions that must be considered in order to achieve this goal must be identified. These generally pertain to basic ecological or conservation principles and theories that will be used to guide the development of a conservation strategy for achieving the overall goal. Examples include:

- In order to conserve biodiversity we must conserve ecosystems. Or, in order to conserve or restore the biological assemblage of a particular area of interest we must take measures to conserve or restore the critical structural features, and functional and evolutionary processes that support this assemblage (Franklin 1993; Grumbine 1994; Leslie et al. 1996; DeLeo and Levin 1997).
- Biodiversity can be described and should be conserved at multiple levels of organization (Whittaker 1962, 1972; Franklin 1993; Noss 1994; Jennings 1996; Leslie et al. 1996).
- Populations, not species, are the fundamental unit of conservation (Leslie et al. 1996; Meffe and Carroll 1997).
- Biodiversity conservation efforts should focus on identifying and collectively conserving the variety of distinct genotypes, populations, species, communities, assemblages, and ecosystem types across the landscape (Angermeier and Schlosser 1995; Grossman et al. 1998; Olson and Dinerstein 1998; Abell et al. 2000).
- Proactive protective measures are less costly and more likely to succeed than restoration actions (Scott et al. 1993).
- Protected areas are critical to the long-term conservation of biodiversity (Rodrigues et al. 2003).
- We cannot directly measure, map, or conserve biodiversity, but we can measure, map, and conserve surrogate biotic and abiotic conservation targets (Margules and Pressey 2000; Roux et al. 2002; Noss 2004).

- Taking measures to conserve a variety of biotic and abiotic targets is the best and most efficient approach to conservation (Kirpatrick and Brown 1994; Noss et al. 2002; Diamond et al. *in press*).
- The structural features and functional processes of a particular location, and how they change through time, provide the habitat template upon which ecological strategies of species develop and evolve through time (Southwood 1977).
- Connectivity among habitats is often essential for meeting the various life history requirements of certain species, as well as, providing essential dispersal avenues during periods of disturbance (Schlosser 1987; Schlosser 1995; Matthews 1998; Fausch et al. 2002; Benda et al. 2004).
- Redundancy in representation of populations or ecosystem types is a safeguard against extinction and also promotes the generation of biodiversity through processes like adaptive radiation, random genetic mutations, and genetic drift (Noss and Cooperrider 1994; Meffe and Carroll 1997; Schaffer and Stein 2000; Groves 2003).
- Priorities should be established and conservation actions taken at multiple spatial scales because different species perceive or utilize the landscape (riverscape) differently and because the critical structural features and functional processes change with the scale of interest (Frissell et al. 1986, Wiens 1989; Angermeier and Schlosser 1995).
- Public ownership does not equate to effective biodiversity conservation, especially in riverine ecosystems (Benke 1990; Allan and Flecker 1993).
- Due to the inherent complexity and dynamic nature of ecosystems, uncertainty is a fundamental component of ecosystem management. This is not an excuse for inaction, but efforts to document and overcome this uncertainty must be a priority (Leslie et al. 1996).
- Because of competing societal demands and the limited human and financial resources dedicated to biodiversity conservation we must recognize that we cannot conserve everything, in fact, in many instances we can only conserve a relatively small fraction of the resource base (Scott et al. 1993; Rodrigues et al. 2003).
- We must therefore strive for efficiency in our conservation efforts and one way to accomplish this is to prioritize locations for conservation and try and maximize the complementarities of protected or focus areas (Margules and Pressey 2000).

This list is long; however, it is by no means complete, and the point here is to show the shear number and complexity of things must be considered in the conservation planning process. By extension, these same principles, theories, and assumptions should also be considered when trying to identify and develop the data/information that will be most useful to the conservation planning process.

Because conservation planning is a geographical exercise, the next step in the process involves selecting a suitable geographic framework. More specifically, this involves selecting, defining, and mapping *planning regions* and *assessment units*. A planning region refers to the area for which the conservation plan will be developed. It defines the spatial extent of the planning effort(s). Assessment units are geographic subunits of the planning region. These units define the spatial grain of analysis and represent those units among which relative quantitative or qualitative comparisons will be made in order to select specific geographic locations as priorities for conservation. Planning regions and assessment units can be variously defined and should be hierarchical in nature to allow for multiscale assessment and planning (Wiens 1989). Boundaries could be based on sociopolitical boundaries (e.g., nations, states, counties, townships), regular grids (e.g., UTM zones or EPA EMAP hexagons), or ecologically defined units (e.g., watersheds or ecoregions). Since biodiversity does not follow sociopolitical boundaries or regular grids, whenever possible, planning regions and assessment units should be based on ecologically defined boundaries since these boundaries provide a more informative ecological context (Bailey 1995; Omernik 1995; Leslie et al. 1996; Higgins 2003).

Next, because it is impossible to directly measure or map biodiversity, surrogate targets for conservation must be identified and mapped (Margules and Pressey 2000; Noss 2004). For the terrestrial component of GAP these surrogates generally include plant communities or vegetation types and vertebrate species (Scott et al. 1991). The assumption here is that by taking measures to conserve these surrogates we are in fact taking measures to also conserve those unmapped or unmappable elements of biodiversity. Because different targets often lead to different answers on which locations should be a priority for conservation, it is generally more effective to use a variety of targets (Kirpatrick and Brown 1994; Noss 2004; Diamond et al. *in press*). Also, because biological survey data are often incomplete, biased, or completely lacking, abiotic targets (e.g., ecosystems, landscapes, or habitats), which are usually easier to map, are often considered as targets (Belbin 1993; Nicholls et al. 1998; Noss et al. 2002; Noss 2004). Angermeier and Schlosser (1995) and Noss (2004) provide excellent discussions on the reasons for using both biotic and abiotic surrogates. Also, a study by Kirpatrick and Brown (1994) revealed that using both biotic and abiotic targets would likely be the most successful approach to representing the range of biodiversity within a planning region.

Once planning regions, assessment units, and conservation targets have been identified and mapped, an overall conservation strategy for selecting priority areas within the planning region must be established. This strategy is built around the fundamental principles, theories, and assumptions that deal with issues such as: How many occurrences of each target should be captured? How much area or length should be captured? Is connectivity essential? If given a choice, should you select locations within existing public lands? Are you interested in selecting relatively high-quality locations for protection efforts or the worst-case scenario for restoration efforts? Unfortunately, for most of these and other pertinent questions there are no detailed guidelines, and even when there is some guidance (e.g., biogeography theory, population viability analysis, or metapopulation theory) the data needed for these more detailed evaluations are usually lacking (Margules and Pressey 2000; Groves 2003). Expert opinion will therefore often play a major role in developing the overall conservation strategy.

In addition to establishing a general conservation strategy, quantitative and/or qualitative assessment criteria, that will be used to make relative comparisons among assessment units, must also be established. These criteria include measures of relative significance or irreplaceability, condition, future threats, costs, and opportunities, which guide the selection of one particular assessment unit over another (Groves 2003). These criteria should also be based upon the previously established fundamental principles, theories, and assumptions.

<u>Examples include</u>

Significance:	species richness, number or percent of endemic species, diversity of habitats, presence of unique habitats, species, communities, or processes
Condition:	percent urban or agriculture, road density, degree of fragmentation, extent of channelization, degree of hydrologic modification, mine density, etc.
Future threat:	recent or projected population trends, potential for future extractive uses
Costs:	acquisition cost, restoration cost, loss of socioeconomic benefits
Opportunities:	leveraging of funds or cooperation among stakeholders, local interest or involvement, ability to receive federal, state, or local funding

After addressing the issues discussed above, the next step involves selecting priority locations within the planning region(s).

Since conservation planning is a geographical exercise, it is no surprise that Geographical Information Systems (GIS) are an invaluable tool. However, because not all of the essential data are in a geospatial format, and because much of the data that are available often lack the necessary detail, expert knowledge must often be incorporated into the planning process. The GIS data provide a more objective, spatially explicit, and comprehensive view of the planning region, while the experts may provide additional and more detailed information for certain locations.

Conservation planning is also a logistical exercise, and once priority areas have been identified, much work remains to be done. The questions of Who? What? How? When? and Why? must all be addressed. Questions such as: Who owns the land within and around each priority area? Who is responsible for implementing on-the-ground conservation actions? What are the critical structural features, functional processes, and species or communities of concern within each priority area? What are the principal threats that must be addressed within each priority area? What are the principal uncertainties surrounding the selection of each priority area and the associated threats and management options? How are we going to eliminate or minimize threats? When should conservation actions be taken, immediately or is there time? Why was each priority area selected, and why is one more "important" than another? Addressing these questions is often more difficult than building the geospatial data sets and associated tools used to select priority areas. However, not addressing these important questions could lead to failure in our efforts to conserve biodiversity (Margules and Pressey 2000). Once these logistical questions have been addressed, then on-the-ground conservation actions can be taken. Monitoring programs must also be established to ensure that conservation efforts are successful and to signal when and possibly how management actions should be modified. Because of the complexity and dynamic nature of ecosystems, adaptive management will be key to long-term conservation of biodiversity (Leslie et al. 1996).

So, what does this abbreviated overview of conservation planning have to do with the Missouri Aquatic GAP Project? Well, in order to adequately assess gaps in biodiversity conservation we must first identify what constitutes a gap and the only way to do this is to develop criteria for what constitutes "effective" conservation. These very criteria are established in the conservation planning process. Building on the solid foundation of the terrestrial component of GAP and going through the above process were the two most influential factors that guided the decisions we faced about the data to be compiled or developed as well as the overall approach to the Missouri Aquatic GAP Project.

The Data

The following overview of the geospatial data developed for the Missouri Aquatic GAP Project explains why and how these data were developed as a precursor to the conservation planning case study that comes later. The process for data development has four steps that are described in detail in the following sections:

1. Classify and map relatively distinct riverine ecosystems at multiple spatial scales.

2. Develop predictive distribution maps for each of the fish, mussel, and crayfish species of Missouri.

3. Develop local, watershed, and upstream riparian stewardship statistics for each stream segment within Missouri.

4. Develop or assemble geospatial data on anthropogenic threats or stressors necessary to quantitatively or qualitatively account for the current conservation status of each ecosystem unit.

Classifying riverine ecosystems

Purpose:

- Provide the ecological and evolutionary context necessary for making truly relative comparisons among two or more locations.
- Provide an ecologically meaningful geographic framework for conservation planning (i.e., planning regions and assessment units).
- Provide surrogate abiotic conservation targets to complement biotic targets.

- Account for broader ecosystem or evolutionary processes that are often not considered with the use of species data alone.
- Account for poorly known or unknown ecosystem processes, aquatic assemblages, and organisms.
- Provide a geographic template and predictor variables for developing predictive species distribution models and maps.
- Provide the necessary reductionist tool for generating inventory statistics, conducting conservation assessments, and developing conservation plans.
- Enhance our understanding of the number and spatial distribution of distinct ecosystem types and riverine assemblages.
- Enhance communication among resource professionals, legislators, and the public.

It is widely accepted that to conserve biodiversity we must conserve ecosystems (Franklin 1993; Grumbine 1994). It is also widely accepted that ecosystems can be defined at multiple spatial scales (Noss 1990; Orians 1993). Consequently, a key objective was to define and map distinct riverine ecosystems (often termed ecological units) at multiple levels. Yet, before distinct riverine ecosystems could be classified and mapped, the question "What factors make an ecosystem distinct?" needed to be answered. Ecosystems can be distinct with regard to their structure, function, or composition (Noss 1990). Structural features in riverine ecosystems include factors such as depth, velocity, substrate, or the presence and relative abundance of habitat types. Functional properties include factors such as flow regime, thermal regime, sediment budgets, energy sources, and energy budgets. Composition can refer to either abiotic (e.g., habitat types) or biotic factors (e.g., species). While both are important, our focus here will be on biological composition, which can be further subdivided into ecological composition (e.g., physiological tolerances, reproductive strategies, foraging strategies, etc...) or taxonomic composition (e.g., distinct species or phylogenies) (Angermeier and Schlosser 1995). Geographic variation in ecological composition is generally closely associated with geographic variation in ecosystem structure and function. For instance, fish species found in streams draining the Central Plains of northern Missouri generally have higher physiological tolerances for low dissolved oxygen and high temperatures than species restricted to the Ozarks, which corresponds to the prevalence of such conditions within the Central Plains (Pflieger 1971; Matthews 1987; Smale and Rabeni 1995a, 1995b). Differences in taxonomic composition, not related to differences in ecological composition, are typically the result of differences in evolutionary history between locations (Mayr 1963). For instance, differences among biological assemblages found on islands despite the physiographic similarity of the islands.

Considering the above, a more specific objective was to identify and map riverine ecosystems that are relatively distinct with regard to ecosystem structure, function, and evolutionary history at multiple levels. To accomplish this an eight-level classification hierarchy was developed in conjunction with The Nature Conservancy's Freshwater Initiative (Higgins 2003) (Figure 7). These eight geographically-dependent and hierarchically-nested levels (described next) were either empirically delineated using biological data or delineated in a top-down fashion using landscape and stream features (e.g., drainage boundaries, geology, soils, landform, stream size, gradient, etc.). These features have consistently been shown to be associated with or ultimately control structural, functional, and compositional variation in riverine ecosystems (Hynes 1975; Dunne and Leopold 1978; Matthews 1998). More specifically, levels 1-3 and 5 account for geographic variation in *taxonomic or genetic-level composition* resulting from distinct evolutionary histories, while levels 4 and 6-8 account for geographic variation in ecosystem structure, function, and *ecological composition* of riverine assemblages. The most succinct way to think about the hierarchy is that it represents a merger between the different approaches taken by biogeographers and physical scientists for tesselating the landscape into distinct geographic units.

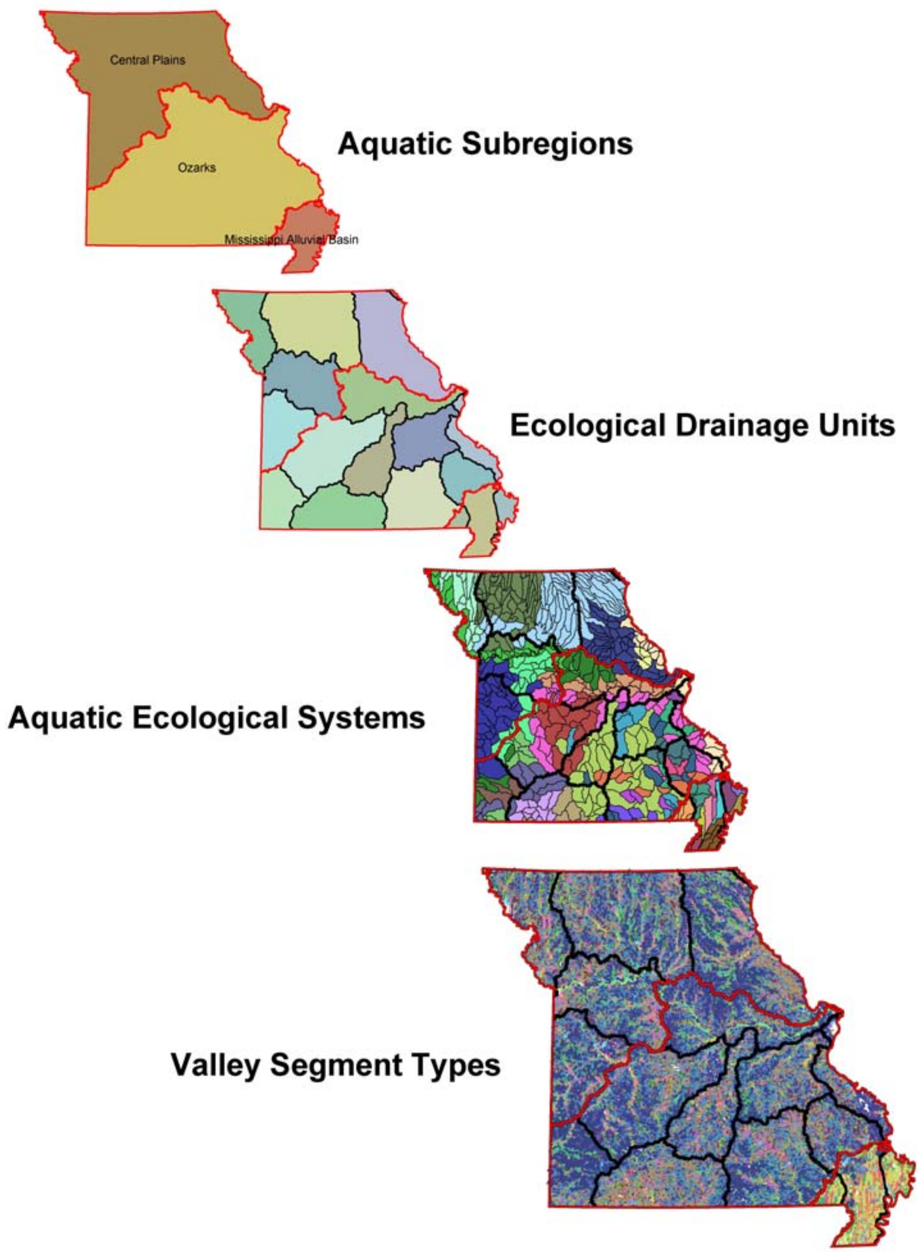

Figure 7. Maps show Levels 4-7 of the MoRAP Aquatic Ecological Classification hierarchy.

Levels 1 – 3: Zone, Subzone, and Region

The upper three levels of the hierarchy are largely zoogeographic strata representing geographic variation in taxonomic (family and species-level) composition of aquatic assemblages across the landscape resulting from distinct evolutionary histories (e.g., Pacific versus Atlantic drainages). For these three levels we adopted the ecological units delineated by Maxwell et al. (1995) who used existing literature and data, expert opinion, and maps of North American aquatic zoogeography (primarily broad family-level patterns for fish and also unique aquatic communities) to delineate each of the geographic units in their hierarchy. More recent quantitative analyses of family-level faunal similarities for fishes conducted by Matthews (1998) provide additional empirical support for the upper levels of the Maxwell et al. (1995) hierarchy. The ecological context provided by these first three levels may seem of little value; however, such global or subcontinental perspectives are critically important for research and conservation (see pp. 261-262 in Matthews 1998). For instance, the physiographic similarities along the boundary of the Mississippi and Atlantic drainages often produce ecologically similar (i.e., functional composition) riverine assemblages within the smaller streams draining either side of this boundary, as Angermeier and Winston (1998) and Angermeier et al. (2000) found in Virginia. However, from a species composition or phylogenetic standpoint, these ecologically similar assemblages are quite different as a result of their distinct evolutionary histories (Angermeier and Winston 1998; Angermeier et al. 2000). Such information is especially important for those states that straddle these two drainages, such as Georgia, Maryland, New York, North Carolina, Pennsylvania, Tennessee, Virginia, and West Virginia, since simple richness or diversity measures not placed within this broad ecological context would fail to identify, separate, and thus conserve distinctive components of biodiversity. The importance of this broader context also holds for those states that straddle the continental divide or any of the major drainage systems of the United States (e.g., Mississippi Drainage vs. Great Lakes or Rio Grande Drainage).

Level 4: Aquatic Subregions

Aquatic Subregions are physiographic or ecoregional substrata of Regions and thus account for differences in the ecological composition of riverine assemblages resulting from geographic variation in ecosystem structure and function (Figure 8). However, the boundaries between Subregions follow major drainage divides to account for drainage-specific evolutionary histories in subsequent levels of the hierarchy. The three Aquatic Subregions that cover Missouri (i.e., Central Plains, Ozarks, and Mississippi Alluvial Basin) largely correspond with the three major aquatic faunal regions of Missouri described by Pflieger (1989). Pflieger used a species distributional limit analysis and multivariate analyses of fish community data to empirically define these three major faunal regions. Subsequent studies examining macroinvertebrate assemblages have provided additional empirical evidence that these Subregions are necessary strata to account for biophysical variation in Missouri's riverine ecosystems (Pflieger 1996; Rabeni et al. 1997; Rabeni and Doisy 2000). Each Subregion contains streams with relatively distinct structural features, functional processes, and aquatic assemblages in terms of both taxonomic and ecological composition.

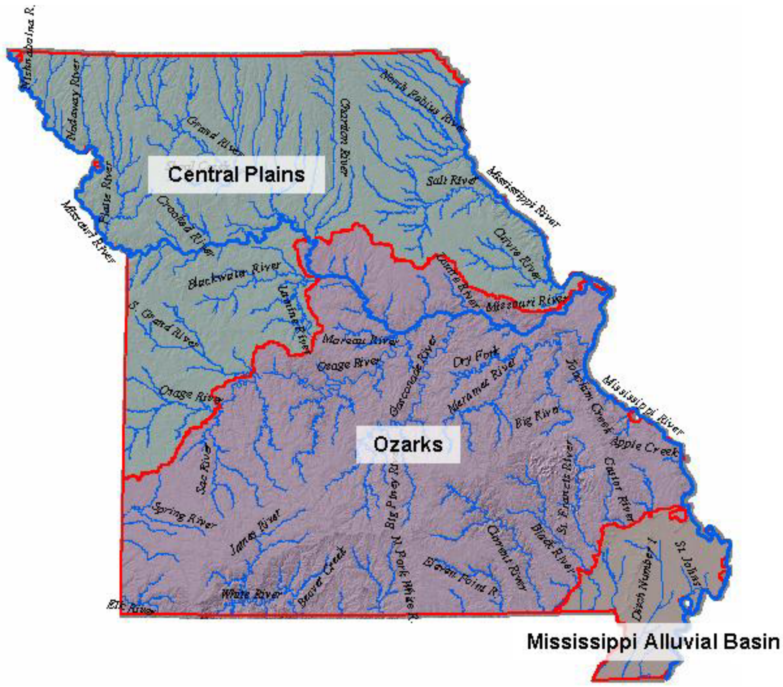

Figure 8. Map showing the boundaries of the three Aquatic Subregions of Missouri.

Level 5: Ecological Drainage Units

Embedded within Aquatic Subregions are geographic variations in taxonomic composition (species- and genetic-level) resulting from the geographically distinct evolutionary histories of the major drainages within each Subregion (Pflieger 1971; Mayden 1987; Mayden 1988; Crandall 1998; Matthews and Robison 1998). Level 5 of the hierarchy, Ecological Drainage Units (EDUs), account for these differences (Figure 9). An initial set of EDUs was empirically defined by grouping USGS 8-digit hydrologic units (HUs) with relatively similar fish assemblages based on the results of multivariate analyses of fish community data (Nonmetric Multidimensional Scaling, Principal Components Analysis, and Cluster Analysis). We then used collection records for three other taxa (crayfish, mussels, and snails) to further examine faunal similarities among the major drainages within each Subregion and refined the boundaries of this draft set of EDUs when necessary. Spatial biases and other problems with the data prohibited including these taxa in the multivariate analyses. In only one instance were the draft boundaries altered. Within the Ozark Aquatic Subregion the subdrainages of the Osage and Gasconade basins consistently grouped together using the methods described above. However, a more general assessment using Jacaard similarity coefficients suggested the need to separate these two drainages. Using just fish community data, the Jacaard similarity coefficient among these two drainages is 86, yet when using combined data for crayfish, mussels, and snails the similarity coefficient drops to only 56.

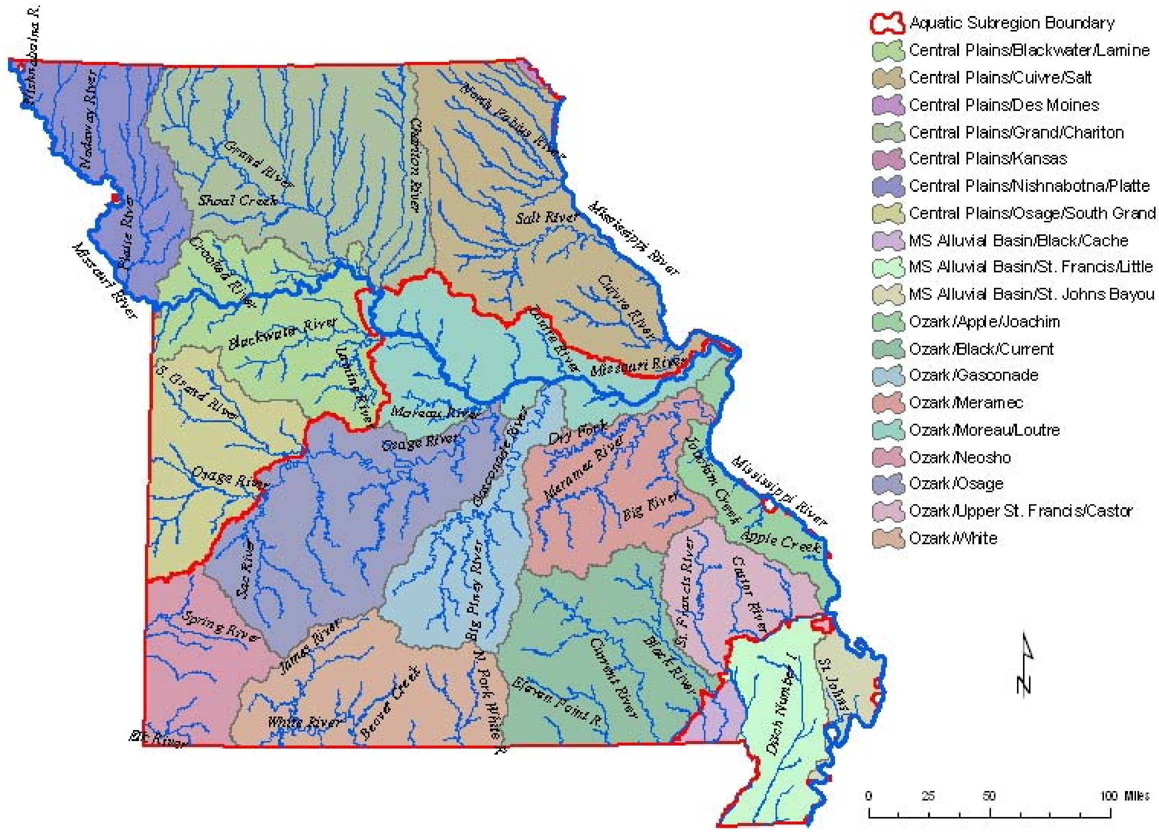

Figure 9. Map of Ecological Drainage Units (EDUs) for Missouri.

EDUs are very much analogous to “islands” when viewed within the context of the surrounding Aquatic Subregion, which is analogous to the “sea” in which the EDUs reside. Our analyses show that the relative similarity (based on centroid distance) of EDUs, within an Aquatic Subregion, is negatively related to the number of river miles separating their respective outlets. Matthews and Robison (1998) found this same relationship for a similar analysis conducted in Arkansas. These results also directly correspond with the relative similarity of assemblages on two or more islands, which is generally negatively related to the distance between the islands (Mayr 1963). Consequently, within a given Aquatic Subregion, all of the EDUs have assemblages with relatively similar ecological composition (e.g., physiological tolerances, reproductive and foraging strategies). However, the taxonomic composition (species and genetic level) of the assemblage of any given EDU is relatively distinct due to evolutionary processes such as adaptive radiation, differences in colonization history, random genetic mutation, etc.

Level 6: Aquatic Ecological System Types

While Aquatic Subregions are relatively distinct in terms of their climatic, geologic, soil, landform, and stream character, they are by no means homogeneous. These finer-resolution variations in physiography also influence the ecological composition of local assemblages (Pflieger 1971; Hynes 1975; Richards et al. 1997; Panfil and Jacobson 2001; Wang et al. 2003). To account for this finer-resolution variation in ecological composition we used multivariate cluster analysis of quantitative landscape data to group small- and large-river watersheds into distinct Aquatic Ecological System Types (AES-Types). AES-Types represent watersheds or subdrainages (that are approximately 100 to 600 mi² with relatively distinct (local and overall watershed) combinations of geology, soils, landform, and groundwater influence (Figure 10). We determined the number of distinct types by examining relativized overlay plots of the cubic clustering criterion, pseudo F-statistic, and the overall R-square as the number of clusters was increased (Calinski and Harabasz 1974; Sarle 1983). Plotting these criteria against the number of clusters and then determining where these three criteria are simultaneously maximized provides a good indication of the number of distinct clusters within the overall data set (Calinski and Harabasz 1974; Sarle 1983; Milligan and Cooper 1985; SAS 1990; Salvador and Chan 2003). Thirty-eight AES-Types were identified for Missouri with this method.

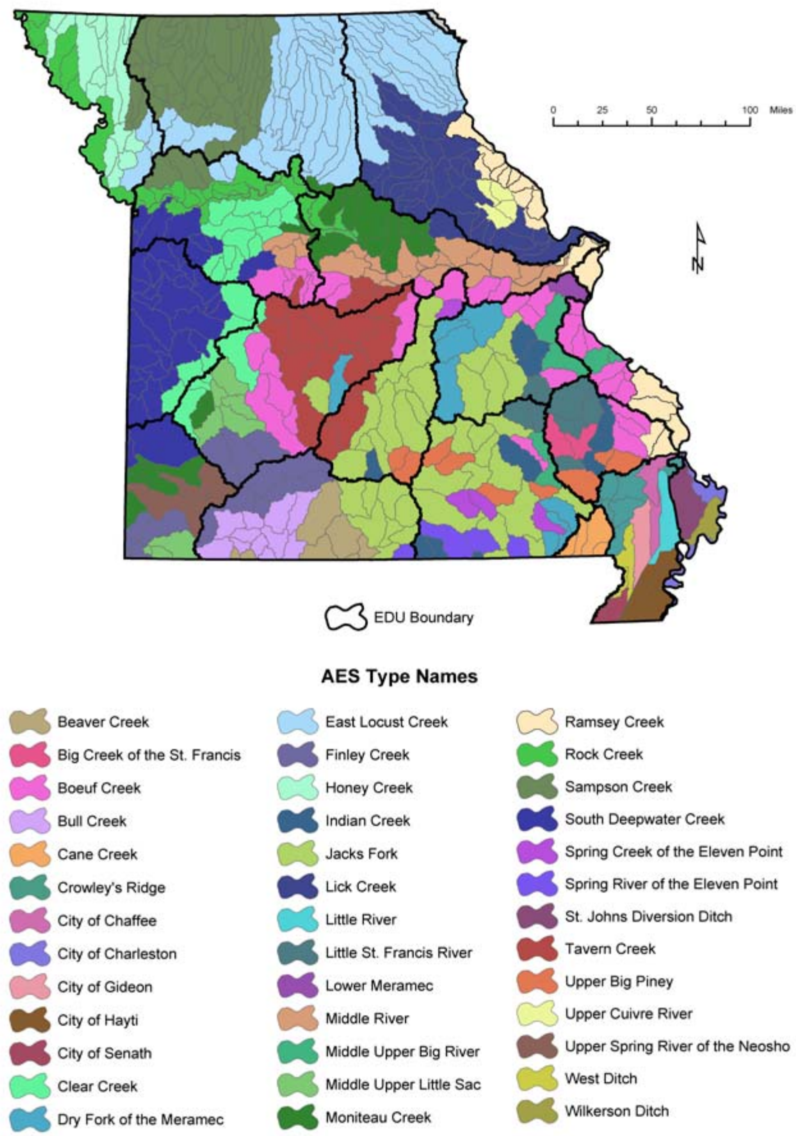

Figure 10. Map of Aquatic Ecological System Types (AES-Types) for Missouri.

AES-Types often initially generate confusion simply because the words or acronym used to name them are unfamiliar. In reality, AES-Types are just “habitat types” at a much broader scale than most aquatic ecologists are familiar with. We have no problem recognizing lake types or wetland types; AES-Types are no different except that they apply specifically to riverine ecosystems. And, just like any habitat classification, there can be multiple instances of the same habitat type. For example, a riffle is a habitat type, yet there are literally millions of individual riffles that occupy the landscape. Each riffle is a spatially distinct habitat, however, they all fall under the same habitat type with relatively similar structural features, functional processes, and ecologically-defined assemblages. The same holds true for AES-Types. Each individual AES is a spatially distinct macrohabitat, however, all individual AESs that are structurally and functionally similar fall under the same AES-Type.

One assumption for this level of the hierarchy is that under natural conditions individual AESs of the same Type will contain streams having relatively similar hydrologic regimes, physical habitat, water chemistries, energy sources, energy and sediment budgets, and ultimately aquatic assemblages. Another assumption is that each AES-Type has a relatively distinct land use potential and vulnerability to a given land use. The reason biological data were not used to empirically define and map AES-Types is that the available data was not suited to the task at hand. At this level of the hierarchy we are interested in differences in the relative abundance of various physiological and functional guilds, not the mere presence or absence of species and existing data are not suited to this more detailed quantification. We are also interested in defining assemblages in a pluralistic context at this level, meaning we are trying to identify relatively distinct complexes of multiple local assemblages (e.g., distinct interacting complexes of headwater, creek, small, and/or large river assemblages).

Level 7: Valley Segment Types

In Level 7 of the hierarchy Valley Segment Types (VSTs) are defined and mapped to account for longitudinal and other linear variation in ecosystem structure and function that is so prevalent in lotic environments (Figure 11). Stream segments within the 1:100,000 USGS/EPA National Hydrography Dataset were attributed according to various categories of stream size, flow, gradient, temperature, and geology through which they flow, and also the position of the segment within the larger drainage network. These variables have been consistently shown to be associated with geographic variation in assemblage composition (Moyle and Cech 1988; Pflieger 1989, Osborne and Wiley 1992; Allan 1995; Seelbach et al. 1997; Matthews 1998). Each distinct combination of variable attributes represents a distinct VST. Stream size classes (i.e., headwater, creek, small river, large river, and great river) are based on those of Pflieger (1989), which were empirically derived with multivariate analyses and prevalence indices. As in the level 6 AESs, VSTs may seem foreign to some, yet if they are simply viewed as habitat types the confusion is removed. Each individual valley segment is a spatially distinct habitat, but valley segments of the same size, temperature, flow, gradient, etc. all fall under the same VST.

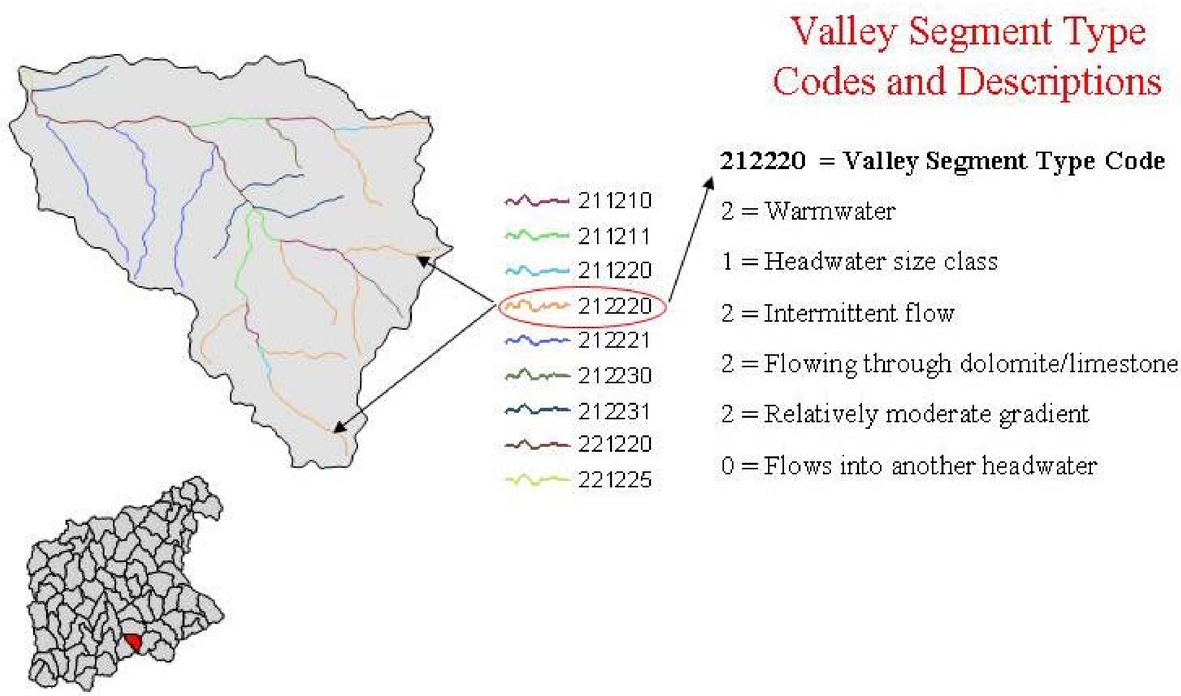

Figure 11. Example of Valley Segment Types (VSTs) for a single 12-digit hydrologic unit. The placement and value of each number in the VST code has meaning and can be deciphered to make informed decisions on the spatial arrangement and relative abundance of stream types across any geographic area of interest.

<u>Level 8: Habitat Types</u>

Units of the final level of the hierarchy, Habitat Types (e.g., high-gradient riffle, lateral scour pool), are simply too small and temporally dynamic to map within a GIS across broad regions or at a scale of 1:100,000. However, we believe it is important to recognize this level of the hierarchy since it is a widely recognized component of natural variation in riverine assemblages (Bisson et al. 1982; Frissell et al. 1986; Peterson 1996; Peterson and Rabeni 2001).

<u>Significant Findings and Recommendations</u>

Since we cannot directly map biodiversity, we must identify suitable surrogates for assessing conservation gaps. Ideally, we should use both biotic and abiotic targets. Abiotic targets should be based on classification systems that define distinct ecosystem/ecological units. When defining these units we must account for structural, functional, and compositional variation across the riverscape and also ensure that at each level of the hierarchy we are delineating interacting systems in order to meet the standard definition of an ecosystem. The difficult part is doing the necessary detective work to identify those watershed and local factors responsible for variation at numerous spatial and temporal scales. The fact that evolutionary history plays such a dominant role in determining geographic variation in community composition dictates the need for a separate classification framework for terrestrial and freshwater ecosystems.

We went to great lengths in our efforts to incorporate existing ecological theory and objective statistical approaches into our classification framework in order to ensure that we were able to account for all three forms of distinctiveness (structure, function, and composition) at multiple spatial scales. However, there is room for improvement if we can overcome some important data limitations. More detailed geology and soil data would allow us to more accurately characterize both watershed and local conditions. Unfortunately, high-resolution geologic data is not standardized among states, which causes problems for creating a seamless classification across state boundaries. Also, the higher resolution 1:24,000 SSURGO soil data have not been converted into a GIS format for many counties across the nation, requiring the use of the 1:250,000 STATSGO soils data.

Stream temperature is likely one of the most influential ecologial parameters influencing the biological composition of streams and is strongly influenced by a wide variety of anthropogenic factors. At present, the thermal regime of most of Missouri's streams (especially in the karst geology of the Ozarks) can only be depicted as either cold or warm. New technologies, such as Forward Looking Infrared Radar imagery (FLIR) provides a powerful tool for more precisely characterizing a streams thermal regime. A pilot project in Oregon has revealed that FLIR data can be used to remotely map stream temperatures to within 1 °C for an entire state (Faux and McIntosh 2000). Using this technology during mid July to early August we could generate a surface temperature datalayer for Missouri that would allow us to more precisely classify Missouri's streams into maximum summer thermal categories (e.g., headwater, maximum summer temperature: 17-19, 20-22, 23-25, 26-28, 29-31, >31). We firmly believe that a statewide stream temperature datalayer would advance our understanding and conservation of Missouri's stream resources more than any other datalayer.

Finally, we also need to take steps to link flow, physical habitat and water chemistry data to NHD. Having spatially explicit data for these critical ecological factors would allow us to more precisely identify significant associations between landscape features and instream habitat. The problem with completing such a task is either the complete lack of data or the lack of data standards. Long term hydrologic data from USGS gaging stations is mainly available for larger streams and the density of the gage network is insufficient for characterizing more subtle differences in hydrologic regimes related to more subtle differences in watershed conditions. Physical habitat and water chemistry data have been collected by a wide variety of state and federal agencies and academic institutions over the years and the lack of a standardized schema for collecting and reporting these data is a major impediment to merging data from these various sources into a single statewide or nationwide geospatial dataset. Nonetheless, efforts must be taken to link existing sampling data to nationally standardized geospatial datasets like the NHD and at the same time national standards for collecting, storing, and reporting these data must become a priority if we are ever going to make progress in sharing this critical environmental data.

Develop predictive distribution maps for fish, mussels, and crayfish

Purpose:

- Only 0.03% of the stream miles in Missouri have been sampled, and much of this data is spatially and temporally biased. Predicted distribution maps provide us with spatially comprehensive biological data at the finest level of our gap analysis (individual stream segment), which is a resolution that managers can comprehend and at which conservation action typically takes place.
- Since we cannot directly measure or map biodiversity, species within those taxa for which adequate sampling data is available and the associated assemblages must serve as surrogate biotic targets for biodiversity conservation, which complement the abiotic targets.
- Conservation values of society are largely biologically based. The public, legislators, and even scientists can more readily comprehend and relate to biologically-based assessments than other measures of biodiversity (e.g., habitat or processes).

To construct our predictive distribution models we compiled nearly 7,000 collection records for fish, mussels, and crayfish and spatially linked these records to the 12-digit USGS/NRCS Hydrologic Unit coverage for Missouri and also to the Valley Segment GIS coverage. Range maps were produced for each of the 315 species, sent out for professional review, and modified as needed. Then we used Decision Tree Analyses to construct predictive distribution models for each species. Ultimately, a total of 571 models were developed to construct reach-specific predictive distribution maps for the 315 species. The resulting maps were merged into a single hyperdistribution (Figure 12), which is related to a database containing information on the conservation status, ecological character, and endemism level of each species.

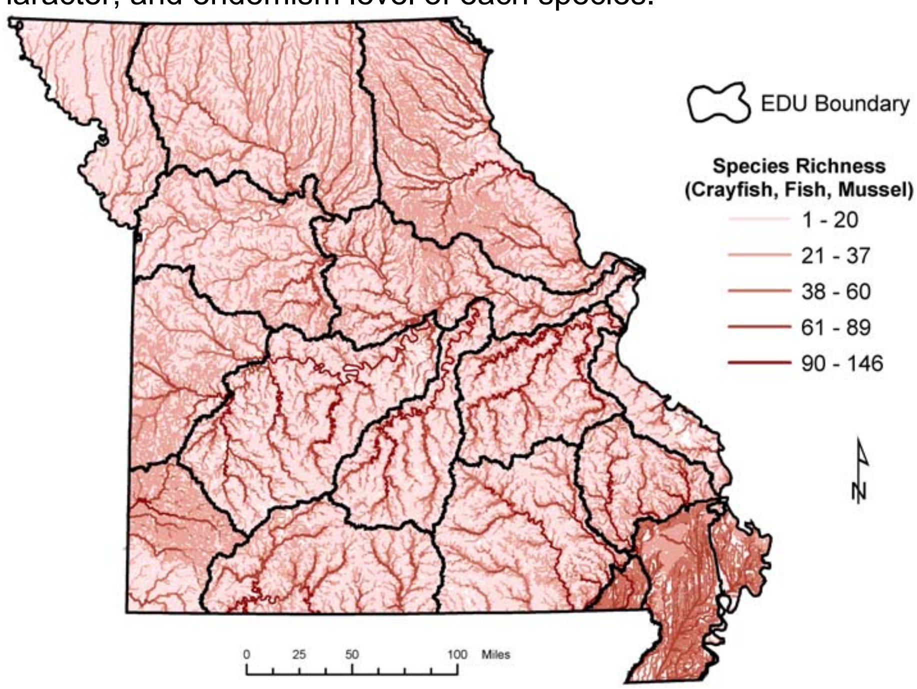

Figure 12. Map of species richness for Missouri, which is based upon predicted distribution models for 315 fish, mussel, and crayfish species. Users can also individually select stream segments within a GIS to obtain a list of the species predicted to occur within each segment of interest.

Users can select an individual stream segment within the Valley Segment coverage and generate a list of those species (and associated information) predicted to occur in that segment under relatively undisturbed conditions (anthropogenic stressors were not or could not be accounted for). An accuracy assessment was conducted for each taxonomic group using independent data. Commission errors, averaged across all three taxa, were relatively high (55%), while omission errors were relatively low (9%). We believe these accuracy statistics can be improved by incorporating watershed variables as predictors as well as by getting more detailed temperature data for valley segments. However, it must be pointed out that this accuracy assessment is fraught with problems mainly related to the inadequacy of the independent data used to evaluate the accuracy of our models (e.g., insufficient length of stream sampled, only a single sample at a single point in time, inefficient gear, and many of the sampling sites were degraded to some degree while our models predict composition under relatively undisturbed conditions). An assessment of a handful of relatively high-quality, intensively-sampled, streams revealed a much lower commission error rate (35%), but also a higher omission error rate (18%).

Significant Findings and Recommendations

Range maps were once viewed as being mainly of interest to naturalists, taxonomists, and biogeographers. However, as resource agencies shift their emphasis from species- and site-specific management to conserving biodiversity over large regions it is becoming increasingly apparent that having precise and accurate range maps is critical to effective conservation. By using GIS and a watershed-based approach to generate range maps for freshwater biota in Missouri we were able to overcome the limited accuracy, precision and utility of hardcopy range maps found in field guides or taxonomic texts. Our GIS-based range maps and associated relational databases allow users to easily generate and visually display a variety of important biological statistics for 315 species to assist with planning, management, and research at several spatial scales. The electronic format of these databases also permits easy editing and updating of distributional data and sharing information over the Internet.

While developing our GIS-based range maps we came to two important realizations. The first realization is that, at present spatially integrating biological survey data among individuals or agencies is a difficult task, to put it mildly. However, this need not be the case and it is our hope that some day sharing biological data among individuals or agencies will be a relatively "painless" and common practice. For this to happen federal, state and tribal resource agencies and university researchers must recognize the benefits of using globally standardized species codes like those provided by ITIS and spatially linking their collection data to nationally standardized geospatial databases like the NHD and HU coverage. This recognition must be accompanied by administrative directives or even agency-wide policies, which encourage these practices by those responsible for collecting or managing biological survey data. Only when these most basic challenges have been overcome can we then begin to address the equally important challenges to sharing biological data outlined by McLaughlin et al. (2001) and Bonar and Hubert (2002).

The second important realization is that, when it comes to the freshwater resources of our nation we are by no means beyond the age of exploration. There needs to be a rekindled interest in the intense and geographically extensive biological surveys that were once so prevalent in the late 1800's and early 1900's due largely to the emphasis placed upon such activities by the U.S. Commission on Fish and Fisheries and several newly formed state fish and game agencies (Hubbs 1964). Our databases show that even in a relatively data "rich" state like Missouri, only 0.03% of the total stream miles have been sampled for fish, mussels, and crayfish. Also, many watersheds have never been sampled for any taxonomic group and a surprising number of watersheds only have less than three samples. Without field data we must resort to modeling or sheer speculation to generate any sort of understanding about the freshwater biota inhabiting these watersheds. Such speculations are especially problematic for conservation efforts directed at rare, threatened or endangered species. Fortunately we now have the ability in Missouri to identify these information gaps and more importantly we can use our databases to develop optimized sampling strategies for filling these gaps.

Habitat-affinity data are lacking for many species, especially mussels and crayfish. There is an obvious need for more basic life-history research. Since habitat affinities often change with life stage there is also a need for life-stage specific habitat-affinity research. Also, most habitat-affinity information that is available pertains to local habitat factors such as depth, velocity and substrate. This "microhabitat" information cannot be used within a GIS to predict a distribution of a species throughout the watersheds in which they are known to occur unless we can first accurately map or model depths, velocities and substrates throughout entire watersheds, which is unlikely. What is needed is habitat-affinity information at the meso and macro scales which reveal associations between a species presence and factors such temperature, stream size, gradient, geology, permanence of flow, and special lotic environments such as springs and wetlands.

Our predictive models utilized local explanatory variables. We firmly believe that our models could be substantially improved by incorporating watershed variables as predictors as well as by getting more detailed temperature data for valley segments. Through a grant from the Missouri Department of Conservation, MoRAP has recently begun developing these very data for every reach of stream within the 1:100,000 NHD. Once completed the models for all 315 species should be reconstructed using this broader suite of potential predictor variables.

The accuracy statistics of our predictive models are very misleading. There are many problems associated with this accuracy assessment related to spatial and temporal sampling "inadequacies" of the independent datasets and with the inherent difference in what we are trying to predict (i.e., biological potential) versus the fact that most of the stream segments sampled in these independent datasets were degraded to some degree. In fact, some of the sites are highly degraded and in such instances we would expect very little correspondence between our predicted assemblage and the assemblage that presently occupies the site. A proper evaluation of the accuracy of our models will require a separate project that identifies relatively high quality sites, which are then sampled intensively throughout relatively long stretches of stream during several seasons and over a period of several years.

Develop local, watershed, and upstream riparian stewardship statistics for each stream segment

Purpose:

- Assess representation of biotic and abiotic targets within the existing matrix of public lands
- Assist with conservation planning by providing decision makers with information on which to base the selection of focus areas for conservation. For instance, a deciding factor between two locations might be the percentage of the watershed in public ownership (e.g., 10% vs. 50%).
- Assist with conservation planning by providing decision makers with information on who owns the stream segment(s) under consideration as well as the percentage of watershed or upstream riparian ownership by each agency or organization.

The GAP stewardship coverage for Missouri was used in conjunction with theValley Segment coverage to identify stream segments flowing through public lands. A special Arc Macro Language (AML) program was used to identify only those segments that have the majority of their length ($\geq$ 51%) within public lands (Figure 13). Each segment flowing through public land is further classified according to the GAP stewardship categories (1-4) and the specific owner. Another AML was used to calculate the percentage of each segment's watershed and upstream riparian area in public ownership by GAP stewardship category and owner (Figure 14). Because the watersheds for many of the stream segments within Missouri extend beyond the state, the stewardship coverages for the neighboring states of Iowa, Kansas, and Nebraska were merged with that of Missouri. With these attributes users can now select any of the more than 170,000 individual stream segments within Missouri and see which segments are flowing through public lands, who owns which segments, what percentage of the overall watershed and upstream riparian area is within public ownership, by either GAP stewardship category or owner.

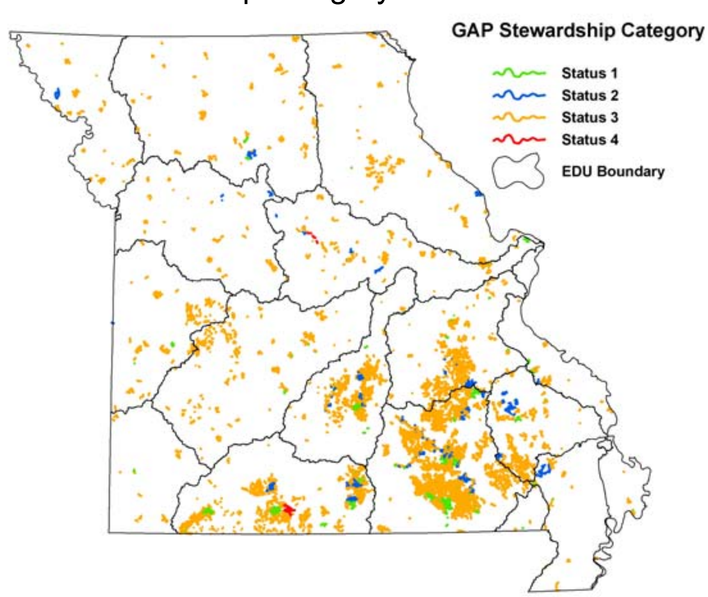

Figure 13. Map of stream segments with greater than 50% of their length flowing through public land categorized according to the four gap stewardship classes.

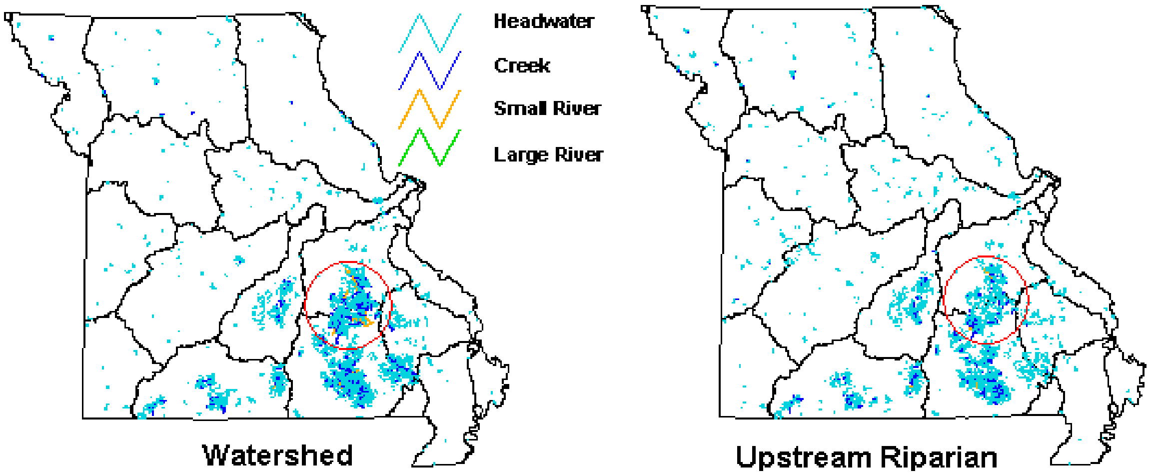

Figure 14. Maps of stream segments with greater than 50% of their watershed and upstream riparian area within public land categorized stream size. Note, no stream classified as large river have greater than 50% of its watershed within public ownership. Also note, within the red circle there are fewer streams classified as small river with greater than 50% of their upstream riparian area in public ownership than those having greater than 50% of their watershed in public ownership. This illustrates the fact that most public lands are situated in the uplands away from the stream channels.

Significant Findings and Recommendations

Public ownership of a stream segment does not ensure long-term protection, since everything that occurs within the watershed influences the ecological integrity of that segment. This is why we calculated the percent of the watershed and upstream riparian area within public ownership for each stream segment. However, it is difficult to effectively use these data for assessing conservation gaps. The reason is that there is a lack of empirical data addressing the question of, "How much is enough?" Is 25, 50, or 75% public ownership within the watershed sufficient to ensure long-term protection? Such thresholds must be identified in a variety of regional settings. Also, there needs to be more stringent standards placed on how public lands are categorized into the four Gap Stewardship categories. When merging the stewardship coverages of adjacent states (Iowa, Kansas, and Nebraska) with Missouri's coverage, we found many discrepancies in how public lands were placed into the four gap stewardship categories. This has serious implications for regional assessments of biodiversity protection. Regional committees are likely needed to address this important issue.

Develop and assemble geospatial data on threats and human stressors

Purpose:

- Because ownership does not ensure effective long-term conservation, measures must be taken to account for human stressors that might significantly impair the ecological integrity of those segments currently within public ownership.
- Assist with conservation planning by providing decision makers with quantitative and qualitative information that can be used to identify relatively high quality locations in order to conserve a given conservation target.

- Assist with conservation planning by providing decision makers with quantitative and qualitative information that can be used to identify what factors threaten the ecological integrity of a particular priority location, and which can then be used to prioritize management objectives.
- Provide spatially explicit information on human stressors to allow resource managers to pinpoint the specific location of the stressor(s) within the drainage network or watershed.

There are a multitude of stressors that negatively affect the ecological integrity of riverine ecosystems (Allan and Flecker 1993; Richter et al. 1997). The first step in any effort to account for anthropogenic stressors is developing a list of candidate causes (U.S. EPA 2000). Working in consultation with a team of aquatic resource professionals, a list of the principal human activities known to affect the ecological integrity of streams in Missouri was generated. Then the best available (i.e., highest resolution and most recent) geospatial data that could be found for each of these stressors was assembled (Table 2). Fortunately, and somewhat surprisingly, data were available for most stressors. However, for some, such as channelized stream segments, there were no available geospatial data, and efforts to develop a coverage of such segments using a sinuosity index proved ineffective. Most of the geospatial data were acquired from the U.S. EPA and the Missouri Departments of Conservation and Natural Resources.

Table 2. List of the GIS coverages, and their sources, that were obtained or created in order to account for existing and potential future threats to freshwater biodiversity in Missouri.

Data layer	**Source**
303d Listed Streams	Missouri Department of Natural Resources (MoDNR)
Confined Animal Feeding Operations	MoDNR
Dam Locations	U.S. Army Corps of Engineers (1996)
Drinking Water Supply (DWS) Sites	U.S. Environmental Protection Agency (USEPA)
High Pool Reservoir Boundaries	Elevations from U.S. Army Corps of Engineers
Industrial Facilities Discharge (IFD) Sites	USEPA
Landcover	1992 MoRAP Landcover Classification
Landfills	Missouri Department of Natural Resources, Air and Land Protection Division, Solid Waste Management Program
Mines - Coal	U.S. Bureau of Mines
Mines - Instream Gravel	Missouri Department of Conservation (MDC)
Mines - Lead	U.S. Bureau of Mines
Mines (other/all)	U.S. Bureau of Mines
Nonnative Species	Missouri Aquatic Gap Project - Predicted Species Distributions; Missouri Resource Assessment Partnership (MoRAP)
Permit Compliance System (PCS) Sites	USEPA; Ref: http://www/epa.gov/enviro
Resource Conservation and Recovery Information System (RCRIS) Sites	USEPA; Ref: http://www.epa.gov/enviro
Riparian Land Cover	MDC
Superfund National Priority List Sites	USEPA; Ref: http://www.epa.gov/enviro
TIGER Road Files	United States Department of Commerce, Bureau of the Census
Toxic Release Inventory (TRI) Sites	USEPA; Ref: http://www.epa.gov/enviro

We initially generated statistics for nearly 50 individual human stressors (e.g., percent urban, lead mine density, degree of fragmentation) for each Aquatic Ecological System in Missouri (see above description). We then used correlation analyses to reduce this overall set of metrics into a final set of 11, relatively uncorrelated, measures of human disturbance (Table 3). Relativized rankings (range 1 to 4) were then developed for each of these 11 metrics (see Table 3). A rank of 1 is indicative of relatively low disturbance for that particular metric, while a rank of 4 indicates a relatively high level of disturbance. These rankings were based on information contained within the literature or simply quartiles when no empirical evidence on thresholds was available. For instance, rankings for percent urban were; 1: 0-5%, 2: 6-10%, 3: 11-20%, and 4: >20%, were based on the results of various studies that have examined the effects of urban land cover on the ecological integrity of stream ecosystems (Klein 1979; Osborne and Wiley 1988; Limburg et al. 1990; Booth 1991; Weaver and Garmen 1994; Booth and Jackson 1997; Wang et al. 2000). However, existing research for percent agriculture has not identified clear thresholds, suggesting that there is a more or less continual decline in ecological integrity with each added percentage of agriculture in the watershed. For this measure of human stress we simply used quartiles, 1: 0-25%, 2: 26-50%, 3: 51-75%, and 4: >75%.

Table 3. The 11 stressor metrics included in the Human Stressor Index (HSI) and the specific criteria used to define the four relative ranking categories for each metric that were used to calculate the HSI for each Aquatic Ecological System.

	Relative Ranks			
Metric	**1**	**2**	**3**	**4**
Number of Introduced Species	1	2	3	4-5
Percent Urban	0-5	5-10	11-20	>20
Percent Agriculture	0-25	26-50	51-75	>75
Density of Road-Stream Crossings (#/mi²)	0-0.24	0.25-0.49	0.5-0.9	$\geq$1
Population Change 1990-2000 (#/mi²)	-42-0	0.1-14	15-45	>45
Degree of Hydrologic Modification and/or Fragmentation by Major Impoundments	1	2 or 3	4 or 5	6
Number of Federally Licensed Dams	0	1-9	10-20	>20
Density of Coal Mines (#/mi²)	0	1-5	6-20	>20
Density of Lead Mines (#/mi²)	0	1-5	6-20	>20
Density of Permitted Discharges (#/mi²)	0	1-5	6-20	>20
Density of Confined Animal Feeding Operations (#/mi²)	0	1-5	5-10	>10

Note: A major impoundment was defined as those that occur on streams classified as small river or larger. The 3-digit qualitative codes used to categorize the degree of hydrologic modification and/or fragmentation can be interpreted as follows.
1: No hydrologic alteration or fragmentation
2: Externally fragmented: obligate aquatic biota could reach adjacent watersheds, but not the MO or MS Rivers without passing through a major impoundment
3: Hydrologically modified: included all innundated subwatersheds and any area downstream of the dam known to have a significantly modified hydrologic regime
4: Both externally fragmented and hydrologically modified: includes those stream segments situated in the interceding area between two major impoundments on the same stream
5: Isolated: obligate aquatic biota could not reach any adjacent watershed without passing through a major impoundment
6: Both Isolated and Hydrologically modified

The relativized rankings for each of these 11 metrics were then combined into a three number Human Stressor Index (HSI). The first number reflects the highest ranking across all 11 metrics (range 1 to 4) (Figures 15 and 16). The last two numbers reflect the sum of the 11 metrics (range 11 to 44) (Figure 17). This index allows you to evaluate both individual and cumulative impacts. For instance, a value of 418, indicates relatively low cumulative impacts (i.e., last two digits = 18 out of a possible 44), however, the first number is a 4, which indicates that one of the stressors is relatively high and potentially acting as a major human disturbance within the ecosystem. Figure 18 provides a map of the resulting HSI scores for each AES in Missouri.

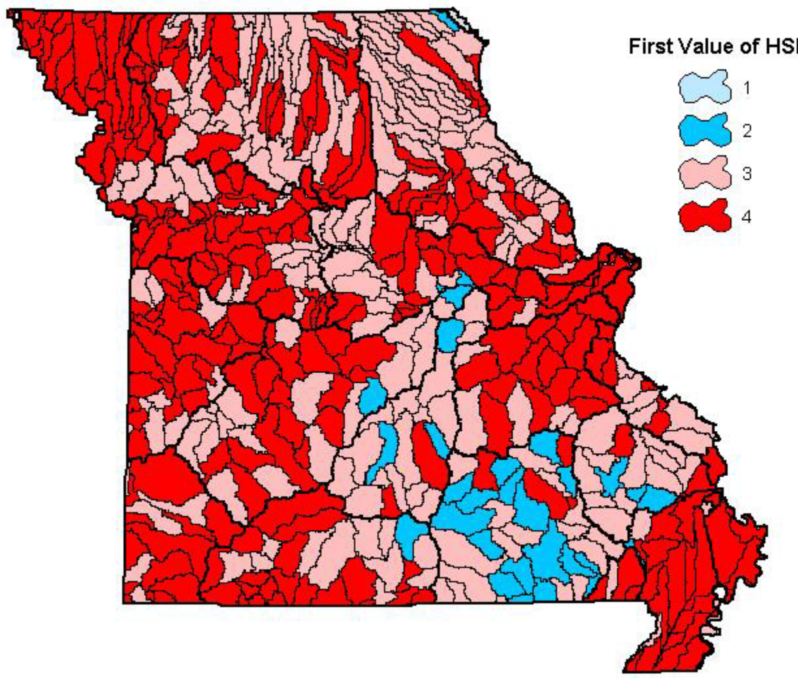

Figure 15. Map showing the first value in the Human Stressor Index for each of the Aquatic Ecological Systems in Missouri. A value of 1 indicates a relatively low level of human disturbance, while a value of 4 indicates a relatively high level of disturbance. None of the AESs polygons received a value of 1.

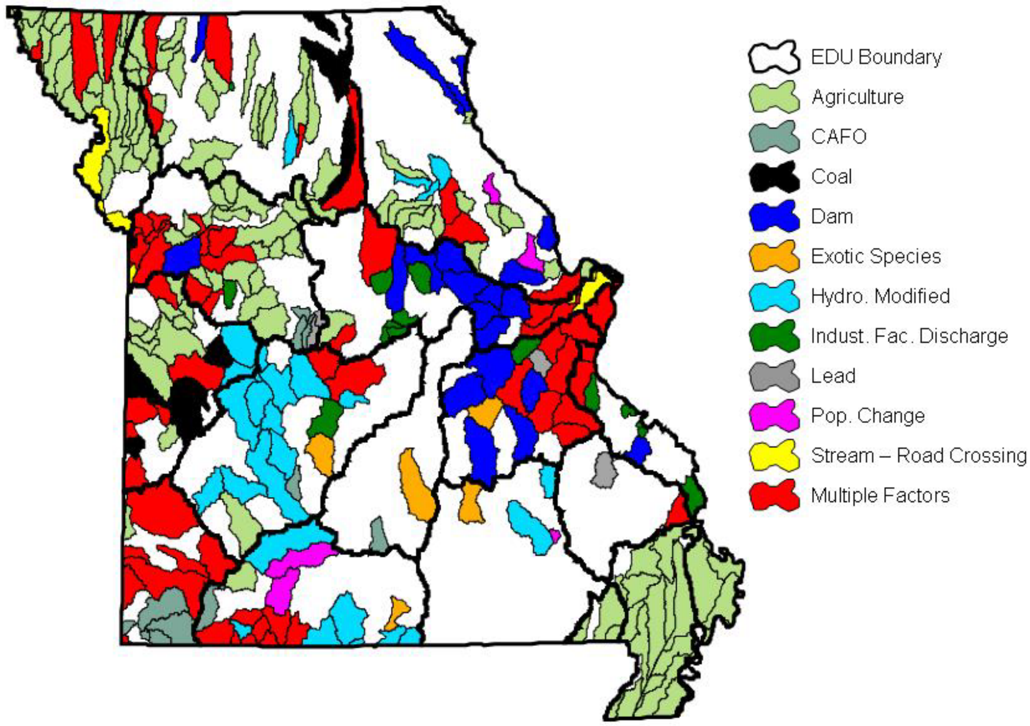

Figure 16. Map showing which Aquatic Ecological Systems received a value of 4 for the first value in the Human Stressor Index, further broken down according to which specific human stressor was responsible for this high value.

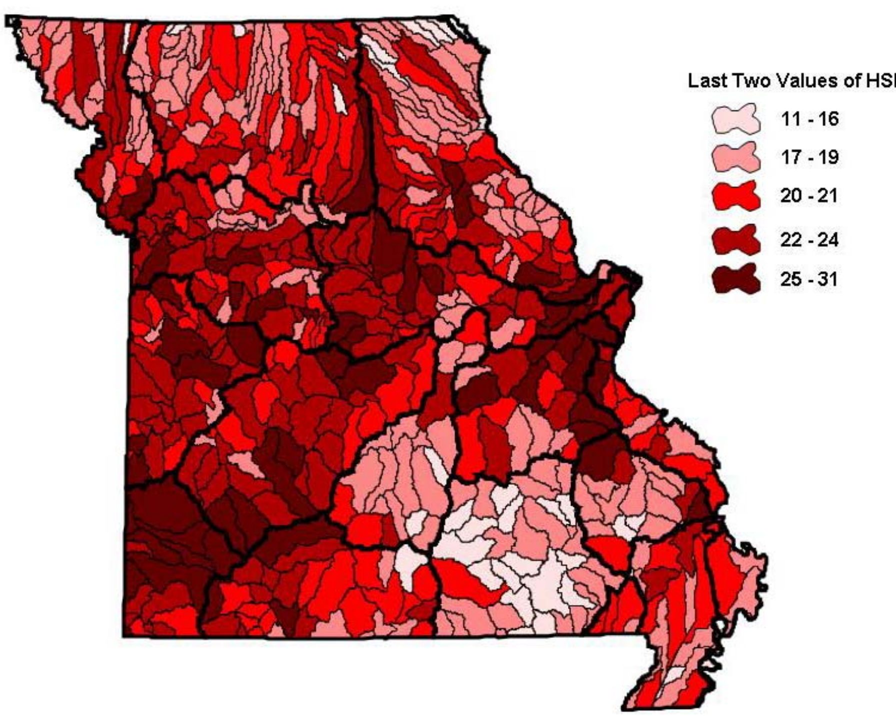

Figure 17. Map showing the last two values in the Human Stressor Index for each of the Aquatic Ecological Systems in Missouri. A value of 11 indicates an extremely low level of cumulative impact. The highest possible value in theory is a 44, however, because some of the 11 metrics used in the index are mutually exclusive (e.g., % urban and %agriculture), the highest obtainable value is unknown. The highest value in Missouri was 31. Basically, the higher the value for these last two digits, the higher degree of cumulative disturbance.

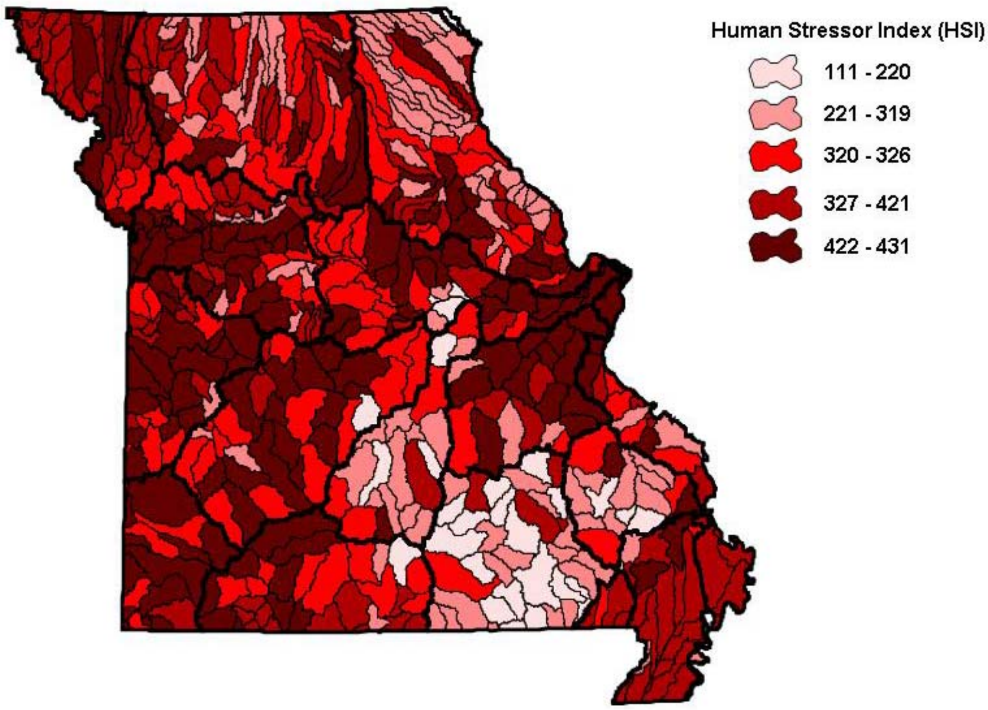

Figure 18. Map showing the composite Human Stressor Index (HSI) values for each Aquatic Ecological System in Missouri. The first number represents the highest value received across all 11 metrics included in the HSI, while the last two digits represent the sum of the scores received for each of the 11 metrics.

Significant Findings and Recommendations

Accounting for human stressors within a GIS is an extremely difficult task. Given the complexity of the issue, nobody should not expect perfect solutions. Describing threats to the "health" of ecosystems with a hanfull of metrics or indicators is similar to what a doctor would advise a human patient: "stop smoking, avoid fatty foods, exercise daily." The metrics used in our Human Stressor Index are of this general character. As we already stated, this index is an admittedly crude measure of human disturbance, however, it is well suited for a coarse-filter assessment since it does act as a red flag. Yet, such general metrics are by no means a substitute for a more detailed assessment of ecosystem health. With this in mind, simply mapping the location of a stressor (e.g., lead mine, permitted discharge) within a GIS is not enough. We must attribute these coverages with contextual information that enables users to more accurately account for the timing, magnitude, duration, and frequency of individual stressors and their combined cumulative impact on riverine ecosystems. There also needs to be substantially more research on how specific stressors influence the ecological integrity of receiving waters. Only through such quantification will we eventually be able to identify thresholds, like Wang et al. (2002) did for percent urban land use within a watershed, or develop models that account for the complex interaction among multiple stressors.

An Aquatic Biodiversity Analysis for Missouri

In fall 2001, federal legislation established a new State Wildlife Grants (SWG) program, which provides funds to state wildlife agencies for conservation of fish and wildlife species, including nongame species. In order to continue receiving federal funds through the SWG program, Congress charged each state and territory with developing a statewide Comprehensive Wildlife Conservation Strategy (CWCS). In Missouri, the Conservation Department (MDC) is responsible for developing the CWCS. MoRAP and worked with MDC to develop customized GIS projects that would assist in the development of a statewide plan for conserving aquatic biodiversity. These customized GIS projects include all of the data compiled or created for the Missouri Aquatic GAP Project, as well as other pertinent geospatial data. At the same time, the MDC developed customized GIS projects for developing a statewide plan for conserving terrestrial biodiversity. Interim results of these two plans will be merged into a single CWCS for the state.

After the customized GIS projects were developed, a team of aquatic resource professionals from around Missouri was assembled. The objective of this team was to address each of the basic components of conservation planning discussed above.

The team formulated the following goal:

Ensure the long-term persistence of native aquatic plant and animal communities, by conserving the conditions and processes that sustain them, so people may benefit from their values in the future.

The team then identified a list of principles, theories, and assumptions that must be considered in order to achieve this goal. Many were similar to those presented above and related mainly to basic principles of stream ecology, landscape ecology, and conservation biology. However, some reflected the personal experiences of team members and the challenges they face when conserving natural resources in regions with limited public land holdings. For instance, one of the assumptions identified by the team was: "Success will often hinge upon the participation of local stakeholders, which will often be private landowners." In fact, the importance of private lands management for aquatic biodiversity conservation was a topic that permeated throughout the initial meetings of the team.

The MoRAP aquatic ecological classification hierarchy was adopted as the geographic framework (i.e., Planning Regions and Asssessment Units) for developing the conservation plan. From this classification hierarchy they selected AES-Types and VSTs as abiotic conservation targets. They also agreed that, in order to fully address biotic targets, a list of target species (fish, mussel, and crayfish) should be developed for each EDU. These lists were developed and they represent species of conservation concern (i.e, global ranks: G1-G3 and state ranks: S1-S3), endemic species, and focal or characteristic species (e.g., top predators, dominant prey species, unique ecological role, etc.).

Next the team crafted a general conservation strategy. The reasoning behind each component of this strategy is best illustrated by discussing what conservation objectives the team hoped to achieve with each component. These reasons are provided in Appendix A.

The conservation strategy

- must develop separate conservation plans for each EDU (Primary Planning Regions);
- whenever possible, represent two distinct spatial occurrences/populations of each target species;
- represent at least one example of each AES-Type within each EDU;
- within each selected AES, represent at least 1 km of the dominant VSTs for each size class (headwater, creek, small river, and large river) as an interconnected complex; and
- represent a least three separate headwater VSTs.

The team then established quantitative and qualitative assessment criteria for making relative comparisons among the assessment units. Since the assessment was conducted at two spatial grains (AES and VST), there exist two different assessment units with assessment criteria developed separately for each.

<u>AES level criteria (listed in order of importance)</u>

- Highest predicted richness of target species
- Lowest Human Stressor Index value (also qualitatively examine individual stressors)
- Highest percentage of public ownership
- Overlaps with existing conservation initiatives
- Ability to achieve connectivity among dominant VSTs across size classes
- When necessary, incorporate professional knowledge of opportunities, constraints, or human stressors not captured within the GIS projects to guide the above decisions.

<u>VST level (listed in order of importance)</u>

- If possible, select a complex of valley segments that contains known viable populations of species of special concern.
- If possible, select the highest quality complex of valley segments by qualitatively evaluating the relative local and watershed condition using the full breadth of available human stressor data.
- If possible, select a complex of valley segments that is already within the existing matrix of public lands.
- If possible, select a complex valley segments that overlaps with existing conservation initiatives or where local support for conservation is high.
- When necessary, incorporate professional knowledge of opportunities, constraints, or human stressors not captured within the GIS projects to guide above decisions.

The conservation strategy and assessment boils down to a five-step process:

1) Use the AES selection criteria to identify one priority AES for each AES-Type within the EDU.
2) Within each priority AES, use the VST selection criteria, to identify a priority complex of the dominant VSTs.
3) For each complex of VSTs create a map of the localized subdrainage (termed "Conservation Opportunity Area" (COA)) that specifically contains the entire interconnected complex.
4) Evaluate the capture of target species.
5) If necessary, select additional COAs to capture underrepresented target species.

The team then used the conservation strategy and assessment process to develop a conservation plan for the Meramec EDU. By using the above process all of the objectives of the conservation strategy were met with 11 COAs (Figure 19). With the initial assessment process and selection criteria, which focus on abiotic targets (AESs and VSTs), 10 separate COAs were selected. These 10 areas represent the broad diversity of watershed and stream types that occur throughout the Meramec EDU. Within this initial set of 10 COAs all but five of the 103 target species were captured (Appendix B). The distribution of all five of these species overlapped within the same general area of the EDU, near the confluence of the Meramec and Dry Fork Rivers. Consequently, all five of these species were captured by adding a single COA (the Dry Fork/Upper Meramec, see Figure 19).

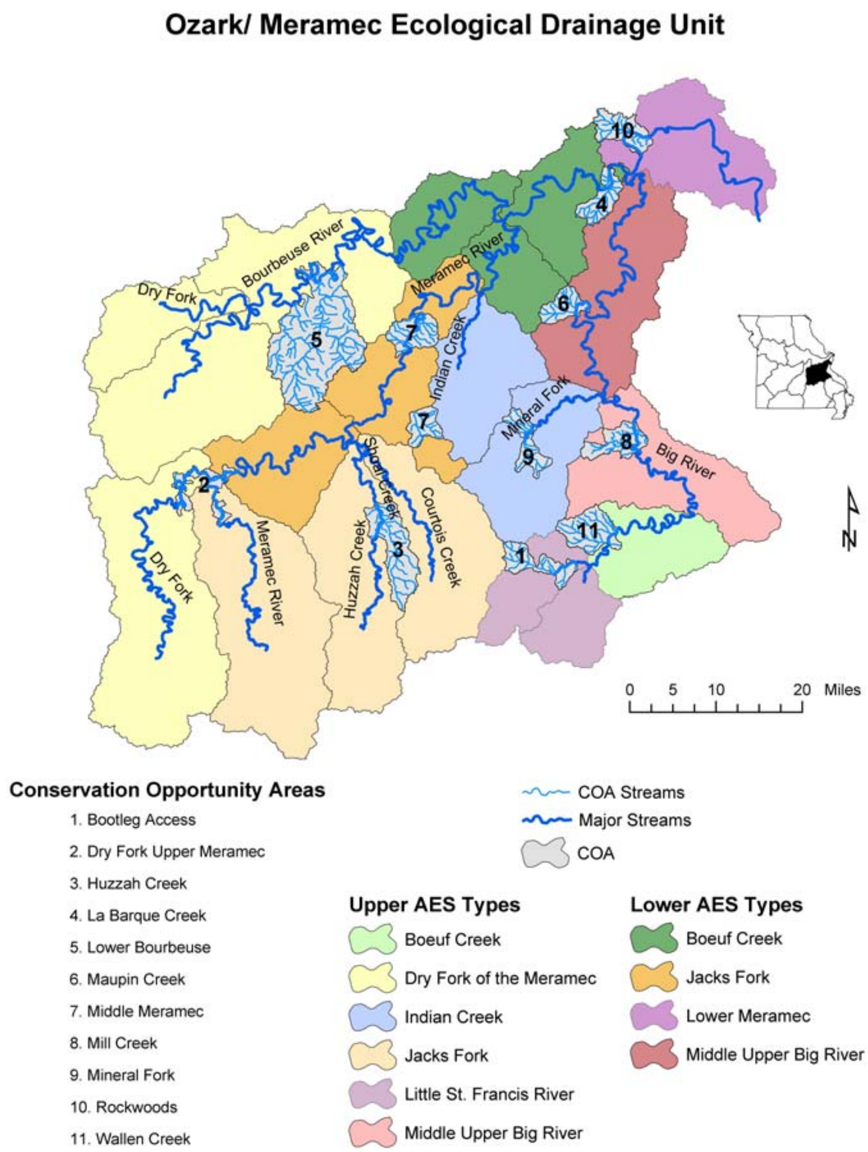

Figure 19. Map the location of 11 Conservation Opportunity Areas, within the Ozark/Meramec EDU, that were selected to meet all of the elements of the basic conservation strategy developed for the freshwater biodiversity conservation planning process in Missouri. The figure also shows the Aquatic Ecological System Types for context. Lower and Upper types differ in terms of their position within the larger drainage network. Specifically, a "Lower AES Type" contains streams classified as Large River and associated headwater and creek tributaries, while Upper types contain streams classified as Small River and their smaller tributaries.

The final set of priority valley segments, within the 11 COAs, constitutes 186 miles of stream. This represents 2.8% of the total stream miles within the Meramec EDU. The COAs themselves represent an overall area of 213 mi², which is 5% of the nearly 4,000 mi² contained within the EDU. Obviously, efforts to conserve the overall ecological integrity of the Meramec EDU cannot be strictly limited to the land area and stream segments within these COAs. In some instances the most important initial conservation action will have to occur outside of a given COA, yet the intent of those actions will be to conserve the integrity of the streams within that COA. Specific attention to, and more intensive conservation efforts within, these 11 COAs provides an efficient and effective strategy for the long-term maintenance of relatively high quality examples of the various ecosystem and community types that exist within this EDU.

In addition to selecting COAs, the team provides information that can assist with the remaining logistical tasks. This information is captured within a database that can be spatially related to the resulting GIS coverage of the focus areas. Specifically, each COA is given a name that generally corresponds with the name of the largest tributary stream, then each of the following items are documented:

- all of the agencies or organizations that own stream segments within the COA and own portions of the overall watershed or upstream riparian area,
- the specific details of why each AES and VST complex was selected,
- any uncertainties pertaining to the selection of the AES or VST complex and if there are any alternative selections that should be further investigated,
- how these uncertainties might be overcome, such as conducting field sampling to evaluate the accuracy of the predictive models or doing site visits to determine the relative influence of a particular stressor,
- all of the management concerns within each COA and the overall watershed,
- any critical structural features, functional processes, or natural disturbances,
- what fish, mussel, and crayfish species exist within the COA for each stream size class, and
- any potential opportunities for cooperative management or working in conjunction with existing conservation efforts.

All of this information is critical to the remaining logistical aspects of conservation planning that must be addressed once geographic priorities have been established. Also, since work cannot be immediately initiated within all of the focus areas there must be priorities established among the focus areas in order to develop a schedule of conservation action (Margules and Pressey 2000). For Missouri, this will initially take place within each EDU and then again from a statewide perspective. An important aspect of generating a “comprehensive” plan is that conservation is often driven by opportunity, and by identifying a portfolio of priority locations quick action can be taken when opportunities arise (Noss et al. 2002).

The selection of COAs has been completed for all 17 EDUs in Missouri. In all, a total of 158 areas were identified through the above assessment process (Figure 20). These COAs provide a blueprint for holistic conservation freshwater ecosystems, as opposed to the patchwork approach used in the past. These areas can be used to guide protection efforts such as land acquisitions, restoration efforts, since many of these areas are degraded to some degree, and regulatory activities like the permit review process administered under the Clean Water Act. These areas also provide an ideal template for research designed to elucidate fundamental ecological processes within riverine ecosystems.

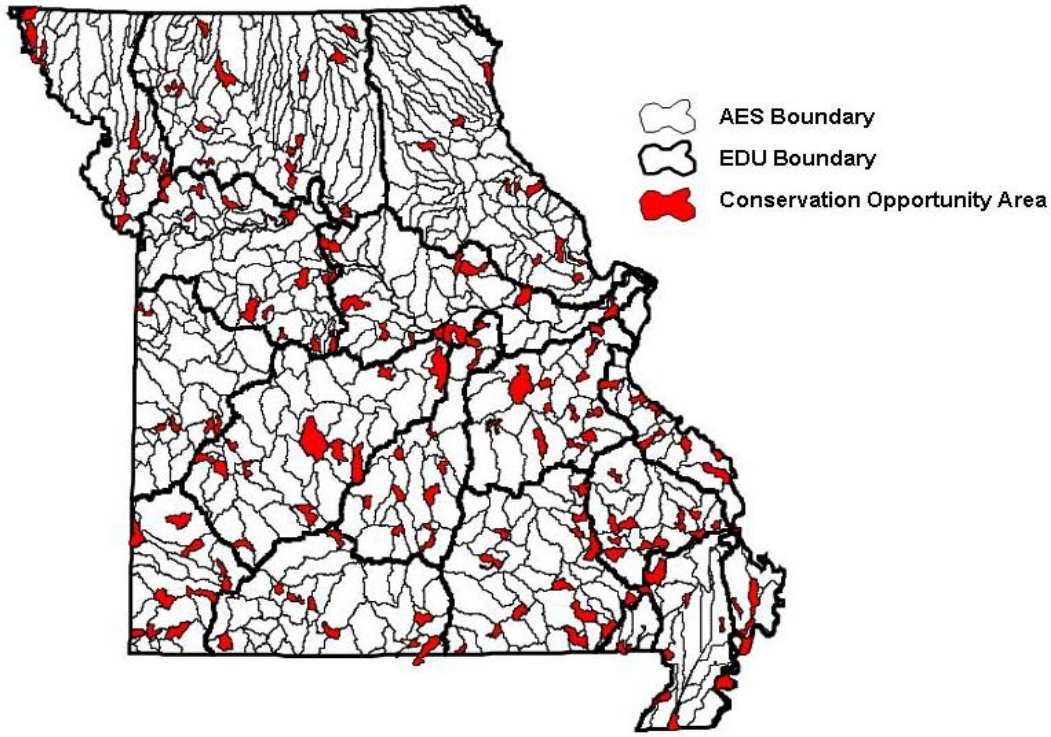

Figure 20. Map showing all 158 freshwater Conservation Opportunity Areas that were selected for Missouri. Taking measures to conserve all of these locations represents an efficient approach to representing multiple examples of all the distinct species, stream types, and watershed types that exist within the state.

Significant Findings and Recommendations

- Local experts are often humbled by the GIS data. Often, what appear to be the best places to conserve are those places that the local managers know little or nothing about. This exemplifies that the world is a big place, and we cannot expect a handful of experts to know every square inch of 4,000+ mi².
- The GIS data are often insufficient and, if solely relied upon, would often lead to poor decisions. There have been several instances where the GIS data point us to a particular location, while the local experts quickly point out that, for example, the sewage treatment facility just upstream has one of the worst spill records in the state, and fish kills occur almost on an annual basis. While the GIS data show the location of the sewage treatment facility, they do not contain this more detailed information.
- Even in the most highly altered and severely degraded landscapes there almost always exist “hidden jewels” that have somehow escaped the massive landscape transformations and other insults in neighboring watersheds. This experience has really revealed the social aspects of land use patterns described by Meyer (1995).
- Ninety-five to 100% of the biotic targets are captured by initially only focusing on abiotic targets (AES-Types and VSTs). This is especially surprising in the Ozark Aquatic Subregion, which contains numerous local endemics with very restricted and patchy distributions. This suggests that these classification units do a good

job of capturing the range of variation in stream characteristics that are partly responsible for the patchy distribution of these species.

- All of the abiotic and biotic targets can be captured within a relatively small fraction of the overall resource base. Unfortunately, the area of interest for managing these focus areas is often substantially larger and much more daunting. However, the reason priority locations were termed “focus areas” was that the streams and assemblages within each priority location are the ultimate focus of conservation action. Even when work is being conducted outside of a focus area, it should be directed at maintaining or restoring conditions within a particular focus area.
- If possible, priorities should be established at a scale that managers can understand and use (e.g., individual stream segments) in order to apply spatially explicit conservation actions. Each team of local experts has found the process much more useful than previous planning efforts that have identified relatively large areas as priorities for conservation. The managers have stated that, because we are selecting localized complexes of specific stream segments, much of the guesswork on where conservation action should be focused has been taken “out of the equation,” which will expedite conservation action.

A Gap Analysis of Freshwater Biodiversity in Missouri

Going through the above conservation planning exercise allowed us to more specifically quantify what constitutes a “gap.” Arguments about the validity of the specific criteria aside (e.g., why not three occurrences of each target species?), the value of this exercise must be viewed in a broad sense. The criteria embedded within the general conservation strategy are a significant improvement over basic species- or habitat-specific stewardship statistics (e.g., percent of each species range within GAP 1 or 2 lands), which are insufficient for quantifying the true extent of the problem since these statistics lack other important contextual information (e.g., connectivity, number of distinct populations, environmental quality).

So, what are the results if the criteria used to identify COAs for the Missouri CWCS are used to assess gaps in the existing conservation network? (see Figure 21). *Note: these statistics pertain to all public lands, not just those meeting criteria for GAP stewardship categories 1 & 2.*

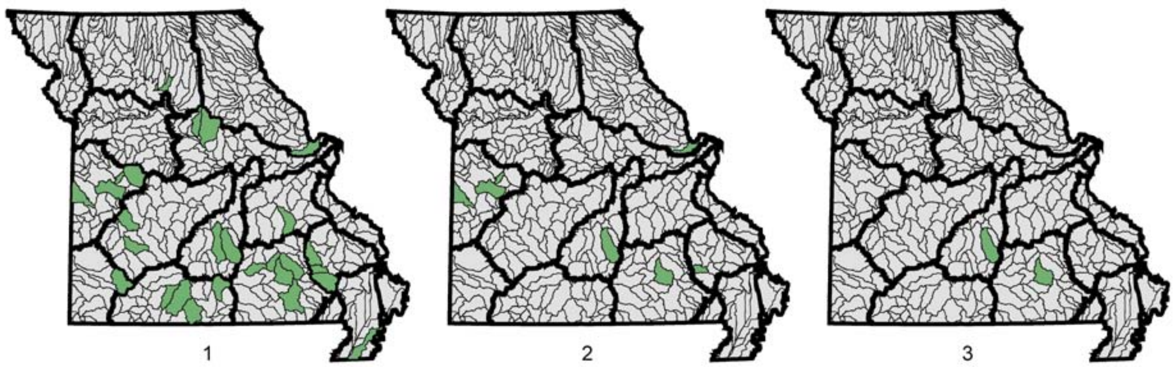

Figure 21. Maps showing the results of a gap analysis of abiotic conservation targets (AESs and VSTs). Map 1 shows which AESs have at least 1 km of the dominant VSTs captured (for all size classes) in existing public lands. Map 2 shows AESs from Map 1 that have the dominant stream types captured as an interconnected complex. Map 3 shows AESs from Map 2 that can be considered relatively undisturbed, after an assessment of human stressors.

How many individual AESs have at least 1 km of the dominant VSTs (for each size class) captured in existing public lands? Answer: **28** (see Map 1, figure 21)

How many of these 28 have the dominant VSTs captured as an interconnected complex? Answer: **7** (see Map 2, figure 21)

How many of these 7 can be considered viable (relatively undisturbed) ecosystems? Answer: **2** (see Map 3, figure 21)

It is apparent from these results and Figure 21 that none of the EDUs have their full range of watershed or stream types currently captured within the existing matrix of public lands. Furthermore, an assessment of the biotic targets reveals that only one of the EDUs have at least two occurrences of all target species captured (Figure 22). However, most EDUs do have a surprisingly high percentage of target species with at least two distinct occurrences within public lands. Still these statistics do not take into consideration critical habitat for each species or ontogenetic changes in habitat requirements. Also, a high percentage of species have only a tiny fraction of their range within existing public lands (Appendices C-F), and most species that currently have zero percent of their range in public lands are considered large river species (Figure 23). From a conservation reserve standpoint, these results paint a bleak picture. However, these results should not come as a surprise, considering the fact that conservation of biodiversity, especially riverine biodiversity, has rarely been considered in the acquisition of public lands.

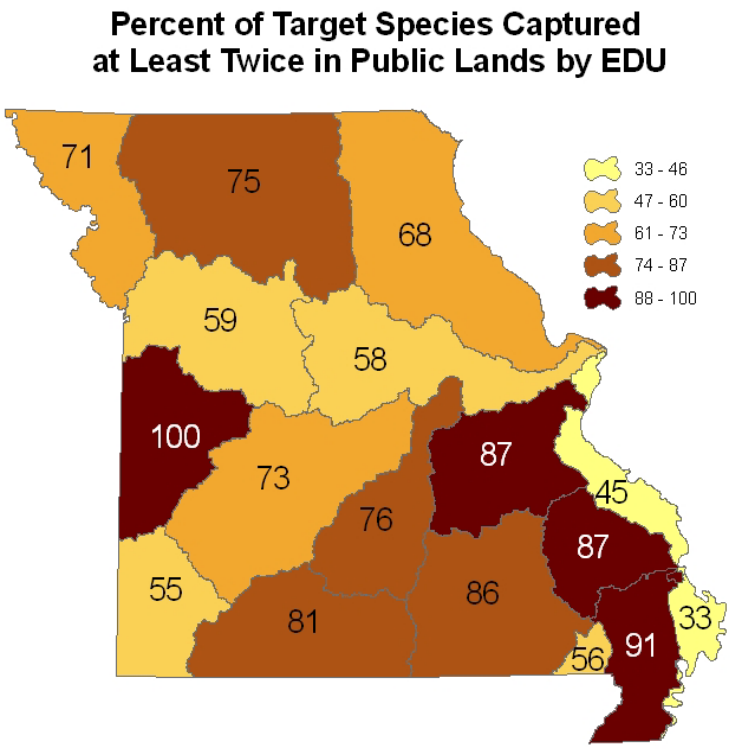

Figure 22. Map showing the percentage of target species within each EDU that have at least two distinct occurrences ("populations") currently captured within the existing matrix of public lands (right). These statistics do not account for critical habitat and include all public lands, regardless of owner or stewardship category. Target species represent state and globally ranked species, locally endemic species, characteristic species, and species that play an important ecological role (top predator or important prey species).

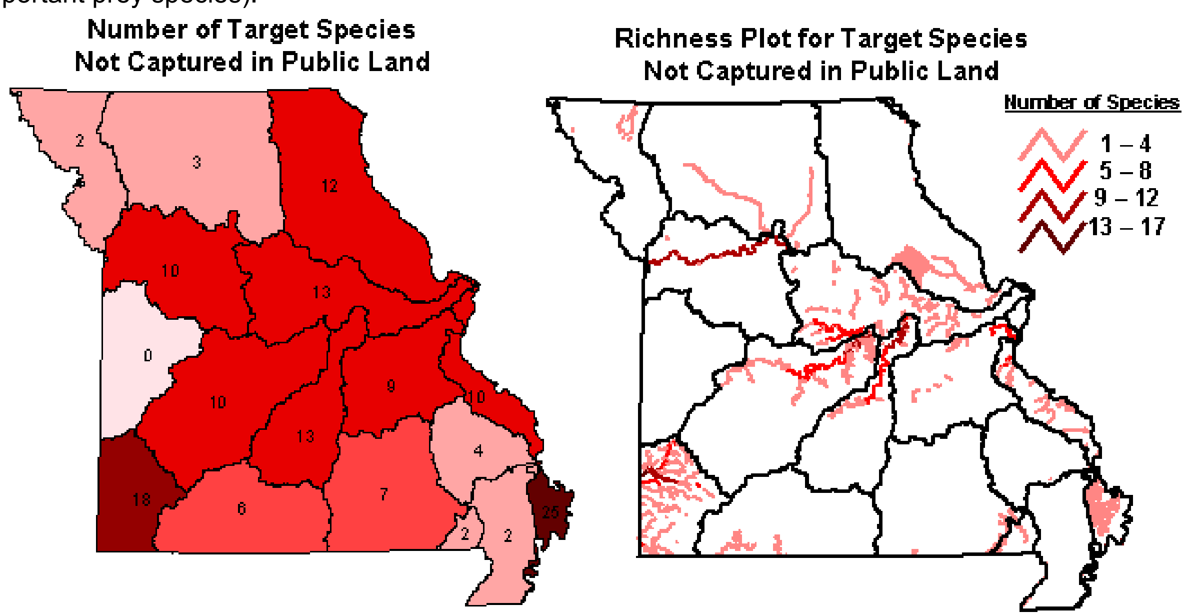

Figure 23. Maps showing the number of target species that are not currently captured in any public land for each EDU (left map) and a richness plot showing the spatial distribution of these species across the state (right map).

Significant Findings and Recommendations

Currently, 7% of the total stream miles in Missouri are in public ownership, yet only a handful of watersheds meet the basic elements of our conservation strategy. Results, thus far, from the statewide conservation planning effort suggest that a reserve network using the outlined conservation strategy would encompass approximately 5-6% of the total stream miles in the state. Consequently, there are more stream miles currently in public ownership than what the conservation planning results suggest is minimally required to represent the "full range" of variation in stream ecosystem types and multiple populations of all fish, mussel, and crayfish species that occur within the state. This irony illustrates the importance of location and spatial arrangement for conserving riverine biodiversity, which heretofore has not been considered in the acquisition of conservation lands. Fortunately, the COAs that have been identified for the Missouri CWCS serve as an important conservation blueprint to help fill the many voids within the existing conservation network.

The foundation provided by the terrestrial component of GAP in conjunction with an understanding of the basic elements of conservation planning were the key elements that have driven the approach taken in the Missouri Aquatic GAP Project. The data developed for the project are currently being used as the core information in a decision support system for developing a statewide freshwater biodiversity conservation plan. Going through the conservation planning process enabled those involved to more specifically define what constitutes effective conservation for a particular ecosystem and thus better define what constitutes a conservation gap. The gap analysis results are not encouraging. However, the results from the conservation planning efforts provide hope that relatively intact ecosystems still exist even in highly degraded landscapes. Results also suggest that a wide spectrum of the abiotic and biotic diversity can be represented within a relatively small portion of the total resource base, with the understanding that for riverine ecosystems the area of conservation concern is often substantially larger than the focus areas.

Selecting COAs is the first step toward effective biodiversity conservation, and the Gap Analysis Program is providing data critical to this task. Yet, establishing geographic priorities is only one of the many steps in the overall process of achieving real conservation. Achieving the ultimate goal of conserving biodiversity will require vigilance on the part of all responsible parties, with particular attention to addressing and coordinating the remaining logistical exercises.

Training, Publications, and Presentations

Training Sessions

MoRAP has held nine training workshops in order to provide training to individuals interested in implementing our methods in their respective states (Appendix G). Specifically, personnel from the following state and federal agencies and academic institutions have participated in these training workshops;

Federal Agencies:
U.S. Department of Defense, U.S. Environmental Protection Agency, U.S. Forest Service, U.S. Fish and Wildlife Service, and U.S. Geological Survey

State Agencies:
Arkansas Game and Fish Commission, Colorado Division of Wildlife, Florida Fish and Wildlife Commission, Illinois Department of Natural Resources, Maine Department of Environmental Protection, Maine Natural Heritage Program, Maryland Department of Natural Resources, Michigan Department of Natural Resources, Missouri Department of Conservation, Missouri Natural Heritage Program, Virginia Department of Game & Inland Fisheries, and Wisconsin Department of Natural Resources

Academic Institutions:
Kansas State University, Iowa State University, Ohio State University, South Dakota State University, University of Georgia, University of Illinois, University of Maine, University of Michigan, University of Nebraska, University of Wyoming, and Virginia Polytechnic and State University

These training workshops have led to the implementation of state or regional aquatic gap projects within the following states: Alabama, Colorado, Florida, Georgia, Hawaii, Illinois, Iowa, Kansas, Maine, Michigan, Minnesota, Montana, Nebraska, New York, Ohio, South Dakota, Virginia, Washington, Wisconsin, and Wyoming.

Overviews and progress reports on these projects can be found on the GAP website at: http://www.gap.uidaho.edu/projects/aquatic/default.htm

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APPENDIX A

Explanation of what we were attempting to achieve with each component of the general conservation strategy that was used to select conservation opportunity areas for protecting freshwater biodiversity throughout Missouri

By attempting to conserve every EDU

- Provide a holistic ecosystem approach to biodiversity conservation, since each EDU represents an interacting biophysical system
- Represent all of the characteristic species and species of concern within the broader Aquatic Subregion and the entire state, since no single EDU contains the full range of species found within the upper levels of the classification hierarchy
- Represent multiple distinct spatial occurrences ("populations") or phylogenies for large-river or wide-ranging species (e.g., sturgeon, catfish, paddlefish), which, from a population standpoint, can only be captured once in any given EDU

By attempting to conserve two distinct occurrences of each Target Species within each EDU

- Provide redundancy in the representation of those species that collectively determine the distinctive biological composition of each EDU in order to provide a safeguard for the longterm persistence of these species

By attempting to conserve an individual example of each AES-Type within each EDU

- Represent a wide spectrum of the diversity of macrohabitats (distinct watershed types) within each EDU
- Account for successional pathways and safeguard against long-term changes in environmental conditions caused by factors like Global Climate Change. For instance, gross climatic or land use changes may make conditions in one AES-Type unsuitable for a certain species, but at the same time make conditions in another AES-Type more favorable for that species
- Represent multiple distinct spatial occurrences ("populations") for species with moderate (e.g., bass or sucker species) and limited dispersal capabilities (e.g., darters, sculpins, certain minnow species, most crayfish and mussels)
- Account for metapopulation dynamics (source/sink dynamics)

By attempting to conserve the dominant VSTs for each size class within a single AES

- Represent the dominant physicochemical conditions within each AES, which we assume represent the environmental conditions to which most species in the assemblage have evolved adaptations for maximizing growth, reproduction and survival (*sensu* Southwood 1977)
- Represent a wide spectrum of the diversity of mesohabitats (i.e., stream types) within each EDU since the dominant stream types vary among AES-Types
- Promote an ecosystem approach to biodiversity conservation by representing VSTs within a single watershed
- Account for metapopulation dynamics (source/sink dynamics)

APPENDIX A, Continued

By attempting to conserve an interconnected complex of dominant VSTs

- Account for seasonal and ontogenetic changes in habitat use or changes in habitat use brought about by disturbance (floods and droughts).
    - For instance, during periods of severe drought many headwater species may have to seek refuge in larger streams in order to find any form of suitable habitat due to the lack of water or flow in the headwaters.
- Account for metapopulation dynamics (source/sink dynamics)
- Further promote an ecosystem approach to conservation by conserving an interconnected/interacting system.

By attempting to conserve at least 3 headwater VSTs within each Focus Area

- Represent multiple distinct spatial occurrences ("populations") for species with limited dispersal capabilities (e.g., darters, sculpins, certain minnow species, most crayfish and mussels)
- Represent multiple high-quality examples of key reproductive or nursery habitats for many species

By attempting to conserve at least a 1 km of each priority VST

- Represent a wide spectrum of the diversity of Habitat Types (e.g., riffles, pools, runs, backwaters, etc.) within each VST and ensure connectivity of these habitats.
- Account for seasonal and ontogenetic changes in local habitat use or changes in habitat use brought about by disturbance (e.g., floods and droughts).
    - For instance, many species require different habitats for foraging (deep habitats with high amounts of cover), reproduction (high gradient riffles), over-wintering (extremely deep habitats with flow refugia or thermally stable habitats like spring branches), or disturbance avoidance (deep or shallow habitats with flow refugia).
- Account for metapopulation dynamics (source/sink dynamics)
- Again, further promote an ecosystem approach to biodiversity conservation by representing an interacting system of Habitat Types.

APPENDIX B

Target species list for the Ozark/Meramec EDU showing global and state conservation ranks (from Missouri Natural Heritage Program), endemism level (corresponds to the MoRAP classification hierarchy), and the number of conservation opportunity areas (COA) in which each species occurs.

TAXON	COMMON	SCIENTIFIC	GRANK	SRANK	ENDEMISM	COA Count
Fish	Alabama shad	Alosa alabamae	G3	S2	Region	3
Fish	banded darter	Etheostoma zonale	G5	S?	Region	8
Fish	banded sculpin	Cottus carolinae	G5	S?	Region	9
Fish	bigeye chub	Notropis amblops	G5	S?	Region	11
Fish	bigeye shiner	Notropis boops	G5	S?	Region	11
Fish	bigmouth shiner	Notropis dorsalis	G5	S?	Region	3
Fish	black redhorse	Moxostoma duquesnei	G5	S?	Region	11
Fish	blacknose shiner	Notropis heterolepis	G4	S2	Subzone	1
Fish	blackspotted topminnow	Fundulus olivaceus	G5	S?	Region	11
Fish	blackstripe topminnow	Fundulus notatus	G5	S?	Region	8
Fish	bleeding shiner	Luxilus zonatus	G5	S?	Subregion	11
Fish	blue sucker	Cycleptus elongatus	G3G4	S3	Region	1
Fish	bluegill	Lepomis macrochirus	G5	S?	Subzone	11
Fish	bluntnose minnow	Pimephales notatus	G5	S?	Subzone	11
Fish	brook silverside	Labidesthes sicculus	G5	S?	Subzone	10
Fish	chestnut lamprey	Ichthyomyzon castaneus	G4	S?	Region	8
Fish	creek chubsucker	Erimyzon oblongus	G5	S?	Subzone	5
Fish	crystal darter	Crystallaria asprella	G3	S1	Region	4
Fish	fantail darter	Etheostoma flabellare	G5	S?	Subzone	11
Fish	flathead chub	Platygobio gracilis	G5	S1	Subzone	1
Fish	flier	Centrarchus macropterus	G5	S3	Subzone	3
Fish	ghost shiner	Notropis buchanani	G5	S2	Region	1
Fish	gilt darter	Percina evides	G4	S?	Region	7
Fish	golden redhorse	Moxostoma erythrurum	G5	S?	Subzone	10
Fish	grass pickerel	Esox americanus	G5	S?	Subzone	10
Fish	gravel chub	Erimystax x-punctatus	G4	S?	Region	8
Fish	green sunfish	Lepomis cyanellus	G5	S?	Region	11
Fish	greenside darter	Etheostoma blennioides	G5	S?	Region	11
Fish	highfin carpsucker	Carpiodes velifer	G4G5	S2	Region	4
Fish	hornyhead chub	Nocomis biguttatus	G5	S?	Region	11
Fish	lake chubsucker	Erimyzon sucetta	G5	S2	Subzone	1
Fish	largemouth bass	Micropterus salmoides	G5	S?	Subzone	11
Fish	largescale stoneroller	Campostoma oligolepis	G5	S?	Region	11
Fish	least brook lamprey	Lampetra aepyptera	G5	S4	Region	6
Fish	logperch	Percina caprodes	G5	S?	Subzone	10
Fish	longear sunfish	Lepomis megalotis	G5	S?	Subzone	11
Fish	Mississippi silvery minnow	Hybognathus nuchalis	G5	S3S4	Region	3
Fish	Missouri saddled darter	Etheostoma tetrazonum	G5	S?	Subregion	11
Fish	mooneye	Hiodon tergisus	G5	S3	Subzone	5
Fish	mottled sculpin	Cottus bairdi	G5	S4	Subzone	11
Fish	northern brook lamprey	Ichthyomyzon fossor	G4	S4	Subzone	2

Appendix B, Continued.

Fish	northern hog sucker	Hypentelium nigricans	G5	S?	Subzone	11
Fish	northern studfish	Fundulus catenatus	G5	S?	Region	11
Fish	orangespotted sunfish	Lepomis humilis	G5	S?	Region	9
Fish	orangethroat darter	Etheostoma spectabile	G5	S?	Region	11
Fish	Ozark minnow	Notropis nubilus	G5	S?	Subregion	10
Fish	paddlefish	Polyodon spathula	G4	S3	Region	4
Fish	plains minnow	Hybognathus placitus	G4	S2	Region	1
Fish	plains topminnow	Fundulus sciadicus	G4	S3	Region	1
Fish	rainbow darter	Etheostoma caeruleum	G5	S?	Subzone	11
Fish	redear sunfish	Lepomis microlophus	G5	S?	Subzone	6
Fish	river darter	Percina shumardi	G5	S3	Region	1
Fish	river redhorse	Moxostoma carinatum	G4	S?	Region	8
Fish	rock bass	Ambloplites rupestris	G5	S?	Subzone	11
Fish	rosyface shiner	Notropis rubellus	G5	S?	Subzone	11
Fish	sand shiner	Notropis stramineus	G5	S?	Subzone	9
Fish	silver chub	Macrhybopsis storeriana	G5	S3	Region	1
Fish	silver redhorse	Moxostoma anisurum	G5	S?	Subzone	9
Fish	silverjaw minnow	Notropis buccatus	G5	S4	Region	6
Fish	slender madtom	Noturus exilis	G5	S?	Region	10
Fish	smallmouth bass	Micropterus dolomieu	G5	S?	Subzone	11
Fish	southern cavefish	Typhlichthys subterraneus	G4	S2S3	Subzone	1
Fish	southern redbelly dace	Phoxinus erythrogaster	G5	S?	Region	11
Fish	spotfin shiner	Cyprinella spiloptera	G5	S?	Subzone	11
Fish	spotted gar	Lepisosteus oculatus	G5	S5	Region	1
Fish	steelcolor shiner	Cyprinella whipplei	G5	S?	Region	11
Fish	stippled darter	Etheostoma punctulatum	G4	S?	Subregion	1
Fish	stonecat	Noturus flavus	G5	S?	Subzone	7
Fish	striped shiner	Luxilus chrysocephalus	G5	S?	Region	11
Fish	suckermouth minnow	Phenacobius mirabilis	G5	S?	Region	7
Fish	wedgespot shiner	Notropis greenei	G5	S?	Subregion	11
Fish	western sand darter	Ammocrypta clara	G3	S2S3	Region	3
Fish	western silvery minnow	Hybognathus argyritis	G4	S2	Region	1
Fish	yellow bullhead	Ameiurus natalis	G5	S?	Subzone	11
Mussel	black sandshell	Ligumia recta	G5	S1S2	Subzone	7
Mussel	butterfly	Ellipsaria lineolata	G4	S?	Region	4
Mussel	creeper	Strophitus undulatus	G5	S?	Subzone	11
Mussel	cylindrical papershell	Anodontoides ferussacianus	G5	S1?	Subzone	1
Mussel	ebonyshell	Fusconaia ebena	G4G5	S1?	Region	2
Mussel	elephantear	Elliptio crassidens	G5	S1	Region	4
Mussel	elktoe	Alasmidonta marginata	G4	S2?	Subzone	11
Mussel	ellipse	Venustaconcha ellipsiformis	G3G4	S?	Subzone	11
Mussel	fawnsfoot	Truncilla donaciformis	G5	S?	Region	7
Mussel	flutedshell	Lasmigona costata	G5	S?	Subzone	11
Mussel	monkeyface	Quadrula metanevra	G4	S?	Region	7
Mussel	northern brokenray	Lampsilis reeveiana brittsi	G3T2	S?	Subregion	11
Mussel	Ouachita kidneyshell	Ptychobranchus occidentalis	G3G4	S2S3	Subregion	5
Mussel	pink mucket	Lampsilis abrupta	G2	S2	Region	3
Mussel	purple wartyback	Cyclonaias tuberculata	G5	S?	Region	5
Mussel	rock pocketbook	Arcidens confragosus	G4	S3	Region	3

Appendix B, Continued.

Mussel	round pigtoe	Pleurobema sintoxia	G4	S?	Region	8
Mussel	salamander mussel	Simpsonaias ambigua	G3	S1?	Region	5
Mussel	scaleshell	Leptodea leptodon	G1	S1S2	Region	4
Mussel	sheepnose	Plethobasus cyphyus	G3	S1	Region	7
Mussel	slippershell mussel	Alasmidonta viridis	G4G5	S?	Subzone	11
Mussel	snuffbox	Epioblasma triquetra	G3	S1	Region	7
Mussel	spectaclecase	Cumberlandia monodonta	G2G3	S3	Region	4
Mussel	threehorn wartyback	Obliquaria reflexa	G5	S?	Region	4
Crayfish	belted crayfish	Orconectes harrisonii	G3	S3	EDU	6
Crayfish	freckled crayfish	Cambarus maculatus	G4	S3	EDU	10
Crayfish	golden crayfish	Orconectes luteus	G5	S?	Subregion	11
Crayfish	saddlebacked crayfish	Orconectes medius	G4	S3?	EDU	10
Crayfish	Salem cave crayfish	Cambarus hubrichti	G2	S3	Subregion	1
Crayfish	spothanded crayfish	Orconectes punctimanus	G4G5	S?	Subregion	11
Crayfish	woodland crayfish	Orconectes hylas	G4	S3?	EDU	4

APPENDIX C

Stewardship statistics for all fish, mussel, and crayfish species in Missouri. This table shows the total miles of stream each species is predicted to occur in (Total) and the percent of that total that is currently captured in existing public land (Public) and by GAP stewardship categories (GAP 1-4). This table is sorted by taxonomic group and common name.

TAXON	COMMON	SCIENTIFIC	TOTAL	GAP1	GAP2	GAP3	GAP4	PUBLIC
Fish	Alabama shad	Alosa alabamae	842	0.12	0	1.07	0	1.19
Fish	alligator gar	Atractosteus spatula	300	0	0	0	0	0
Fish	American brook lamprey	Lampetra appendix	209	0.96	1.44	42.11	0	44.51
Fish	American eel	Anguilla rostrata	2365	1.18	0.93	6.34	0.08	8.53
Fish	Arkansas darter	Etheostoma cragini	2926	0.07	0	0.65	0	0.72
Fish	Arkansas saddled darter	Etheostoma euzonum	266	0.75	0.75	23.68	0	25.18
Fish	banded darter	Etheostoma zonale	3224	1.05	1.15	7.35	0	9.55
Fish	banded pygmy sunfish	Elassoma zonatum	5249	0.08	0.57	1.51	0	2.16
Fish	banded sculpin	Cottus carolinae	13286	0.84	1.02	7.32	0	9.18
Fish	bantam sunfish	Lepomis symmetricus	59	1.69	42.37	15.25	0	59.31
Fish	bigeye chub	Notropis amblops	3169	1.14	0.85	9.69	0	11.68
Fish	bigeye shiner	Notropis boops	5804	0.62	0.78	5.93	0	7.33
Fish	bighead carp	Hypophthalmichthys nobilis	1197	0.08	0	0.75	0.17	1
Fish	bigmouth buffalo	Ictiobus cyprinellus	8205	0.21	0.49	4.2	0.02	4.92
Fish	bigmouth shiner	Notropis dorsalis	29776	0.05	0.18	1.3	0.03	1.56
Fish	black buffalo	Ictiobus niger	3758	0.11	0.56	4.71	0	5.38
Fish	black bullhead	Ameiurus melas	80937	0.09	0.21	3.11	0.01	3.42
Fish	black crappie	Pomoxis nigromaculatus	3472	0.14	0.69	5.18	0.06	6.07
Fish	black redhorse	Moxostoma duquesnei	5570	0.66	0.9	7.29	0	8.85
Fish	blacknose shiner	Notropis heterolepis	1695	0.24	0.06	3.95	0	4.25
Fish	blackside darter	Percina maculata	5602	0.09	0.54	2.21	0	2.84
Fish	blackspotted topminnow	Fundulus olivaceus	15781	0.5	0.74	4.07	0	5.31
Fish	blackstripe topminnow	Fundulus notatus	17850	0.07	0.27	2.2	0	2.54
Fish	blacktail shiner	Cyprinella venusta	5393	0.17	0.57	2.32	0	3.06
Fish	bleeding shiner	Luxilus zonatus	7949	0.81	0.79	6.37	0	7.97
Fish	blue catfish	Ictalurus furcatus	1519	0.07	0	0.92	0.13	1.12
Fish	blue sucker	Cycleptus elongatus	1827	0.11	0.05	2.41	0.11	2.68
Fish	bluegill	Lepomis macrochirus	107924	0.31	0.35	4.7	0.03	5.39
Fish	bluestripe darter	Percina cymatotaenia	832	0.12	2.76	2.64	0	5.52
Fish	bluntface shiner	Cyprinella camura	423	0	0	0.95	0	0.95
Fish	bluntnose darter	Etheostoma chlorosomum	7605	0.08	0.39	1.92	0	2.39
Fish	bluntnose minnow	Pimephales notatus	77977	0.2	0.27	2.82	0.01	3.3
Fish	bowfin	Amia calva	1252	0.16	0.24	3.75	0	4.15
Fish	brassy minnow	Hybognathus hankinsoni	1582	0	0	1.64	0	1.64
Fish	brindled madtom	Noturus miurus	738	0	0.14	5.83	0	5.97
Fish	brook darter	Etheostoma burri	1903	1.05	1.21	20.7	0	22.96
Fish	brook silverside	Labidesthes sicculus	14392	0.28	0.44	3.61	0	4.33
Fish	brown bullhead	Ameiurus nebulosus	68	0	39.71	8.82	0	48.53
Fish	brown trout	Salmo trutta	130	0	0.77	24.62	0	25.39
Fish	bullhead minnow	Pimephales vigilax	6860	0.09	0.48	2.03	0	2.6
Fish	burbot	Lota lota	323	0	0	0	0.62	0.62
Fish	cardinal shiner	Luxilus cardinalis	3695	0.05	0	0.89	0	0.94

Appendix C, Continued.

Fish	central mudminnow	Umbra limi	6	0	0	0	0	0
Fish	central stoneroller	Campostoma anomalum	100268	0.33	0.34	4.95	0.03	5.65
Fish	chain pickerel	Esox niger	1081	4.63	3.89	25.44	0	33.96
Fish	channel catfish	Ictalurus punctatus	10624	0.23	0.59	3.77	0.02	4.61
Fish	channel darter	Percina copelandi	333	0	0	1.2	0	1.2
Fish	channel shiner	Notropis wickliffi	676	0.15	0	0	0	0.15
Fish	checkered madtom	Noturus flavater	665	1.65	1.8	16.24	0	19.69
Fish	chestnut lamprey	Ichthyomyzon castaneus	3250	0.22	0.49	6.25	0.06	7.02
Fish	common carp	Cyprinus carpio	24949	0.21	0.39	3.13	0.01	3.74
Fish	common shiner	Luxilus cornutus	17076	0.03	0.08	1.8	0.04	1.95
Fish	creek chub	Semotilus atromaculatus	98853	0.32	0.34	4.85	0.03	5.54
Fish	creek chubsucker	Erimyzon oblongus	22744	0.87	1.11	11.35	0	13.33
Fish	crystal darter	Crystallaria asprella	870	0.11	0.11	4.14	0	4.36
Fish	Current darter	Etheostoma uniporum	6847	1.87	1.36	19.92	0	23.15
Fish	cypress darter	Etheostoma proeliare	6286	0.11	0.49	1.94	0	2.54
Fish	cypress minnow	Hybognathus hayi	156	0	0	2.56	0	2.56
Fish	dollar sunfish	Lepomis marginatus	4	0	0	75	0	75
Fish	dusky darter	Percina sciera	5114	0.12	0.61	1.76	0	2.49
Fish	duskystripe shiner	Luxilus pilsbryi	7467	1.31	1	9	0.31	11.62
Fish	emerald shiner	Notropis atherinoides	5789	0.14	0.43	2.66	0.03	3.26
Fish	fantail darter	Etheostoma flabellare	54113	0.46	0.51	7.49	0.02	8.48
Fish	fathead minnow	Pimephales promelas	49796	0.04	0.12	1.66	0.02	1.84
Fish	flathead catfish	Pylodictis olivaris	6626	0.21	0.5	3.73	0.03	4.47
Fish	flathead chub	Platygobio gracilis	1071	0.09	0	0.93	0.19	1.21
Fish	flier	Centrarchus macropterus	1624	0.37	0.68	1.91	0	2.96
Fish	freckled madtom	Noturus nocturnus	1741	0.29	0.17	7.58	0	8.04
Fish	freshwater drum	Aplodinotus grunniens	7464	0.2	0.66	4.01	0.03	4.9
Fish	ghost shiner	Notropis buchanani	3575	0.03	0.08	3.27	0.06	3.44
Fish	gilt darter	Percina evides	1285	0.23	2.1	10.66	0	12.99
Fish	gizzard shad	Dorosoma cepedianum	13567	0.37	0.61	3.55	0.01	4.54
Fish	golden redhorse	Moxostoma erythrurum	6897	0.51	0.61	5.74	0	6.86
Fish	golden shiner	Notemigonus crysoleucas	26905	0.05	0.25	1.87	0.02	2.19
Fish	golden topminnow	Fundulus chrysotus	20	0	0	0	0	0
Fish	goldeye	Hiodon alosoides	2646	0.34	0.26	3.51	0	4.11
Fish	goldfish	Carassius auratus	31	0	3.23	3.23	0	6.46
Fish	goldstripe darter	Etheostoma parvipinne	9	0	0	11.11	0	11.11
Fish	grass carp	Ctenopharyngodon idella	972	0.1	0	0	0.21	0.31
Fish	grass pickerel	Esox americanus	22544	0.47	0.73	7.94	0.05	9.19
Fish	gravel chub	Erimystax x-punctatus	2158	0.14	1.07	4.31	0	5.52
Fish	green sunfish	Lepomis cyanellus	107840	0.31	0.35	4.7	0.03	5.39
Fish	greenside darter	Etheostoma blennioides	5017	0.72	1	7.87	0	9.59
Fish	harlequin darter	Etheostoma histrio	147	0	0	2.72	0	2.72
Fish	highfin carpsucker	Carpiodes velifer	1496	0.2	1.8	4.61	0	6.61
Fish	hornyhead chub	Nocomis biguttatus	25486	0.87	0.77	9.13	0.02	10.79
Fish	inland silverside	Menidia beryllina	90	0	0	0	0	0
Fish	ironcolor shiner	Notropis chalybaeus	1588	0	0	0.5	0	0.5
Fish	Johnny darter	Etheostoma nigrum	32799	0.05	0.1	1.8	0	1.95
Fish	lake chubsucker	Erimyzon sucetta	2768	0.14	0.4	1.19	0	1.73
Fish	lake sturgeon	Acipenser fulvescens	962	0.1	0	0	0.21	0.31

Appendix C, Continued.

Fish	largemouth bass	Micropterus salmoides	46762	0.2	0.33	2.81	0.02	3.36
Fish	largescale stoneroller	Campostoma oligolepis	10429	0.84	0.76	6.26	0	7.86
Fish	least brook lamprey	Lampetra aepyptera	4525	1.02	1.35	8.66	0.04	11.07
Fish	least darter	Etheostoma microperca	2073	0.05	0.05	3.96	0	4.06
Fish	logperch	Percina caprodes	9406	0.31	0.43	4.61	0	5.35
Fish	longear sunfish	Lepomis megalotis	33275	0.46	0.56	5.44	0.01	6.47
Fish	longnose darter	Percina nasuta	169	0	0	10.06	0	10.06
Fish	longnose gar	Lepisosteus osseus	10437	0.2	0.63	3.15	0.02	4
Fish	mimic shiner	Notropis volucellus	2785	0.11	0.83	2.91	0	3.85
Fish	Mississippi silvery minnow	Hybognathus nuchalis	1013	0.2	0.2	8.39	0	8.79
Fish	Missouri saddled darter	Etheostoma tetrazonum	2335	0.13	1.16	3.94	0	5.23
Fish	mooneye	Hiodon tergisus	1358	0.29	0.74	6.11	0	7.14
Fish	mottled sculpin	Cottus bairdi	5060	0.26	0.69	4.84	0	5.79
Fish	mountain madtom	Noturus eleutherus	11	0	0	9.09	0	9.09
Fish	mud darter	Etheostoma asprigene	915	0.11	0.11	1.2	0	1.42
Fish	Neosho madtom	Noturus placidus	3	0	0	0	0	0
Fish	Niangua darter	Etheostoma nianguae	827	0	0	4.96	0	4.96
Fish	northern brook lamprey	Ichthyomyzon fossor	539	0.56	4.45	1.67	0	6.68
Fish	northern hog sucker	Hypentelium nigricans	5433	0.66	0.94	7.47	0	9.07
Fish	northern pike	Esox lucius	339	0	0	2.65	0	2.65
Fish	northern studfish	Fundulus catenatus	10274	0.85	0.76	6.43	0	8.04
Fish	orangespotted sunfish	Lepomis humilis	24535	0.09	0.26	2.49	0.02	2.86
Fish	orangethroat darter	Etheostoma spectabile	72510	0.23	0.26	3.99	0.04	4.52
Fish	Ozark bass	Ambloplites constellatus	1190	0.17	0.92	7.48	0	8.57
Fish	Ozark chub	Erimystax harryi	1022	0.39	1.76	19.96	0	22.11
Fish	Ozark madtom	Noturus albater	1173	2.3	3.41	19.01	0	24.72
Fish	Ozark minnow	Notropis nubilus	20247	0.71	0.84	6.95	0	8.5
Fish	Ozark sculpin	Cottus hypselurus	1980	1.67	1.72	12.32	0	15.71
Fish	Ozark shiner	Notropis ozarcanus	488	2.05	1.64	21.93	0	25.62
Fish	paddlefish	Polyodon spathula	2349	0.17	0.13	6.47	0.09	6.86
Fish	pallid shiner	Notropis amnis	1091	0.09	0.09	3.57	0	3.75
Fish	pallid sturgeon	Scaphirhynchus albus	858	0.12	0	0	0.23	0.35
Fish	pirate perch	Aphredoderus sayanus	11285	0.12	0.76	7.35	0	8.23
Fish	plains killifish	Fundulus zebrinus	11	0	0	0	0	0
Fish	plains minnow	Hybognathus placitus	2998	0.33	0.13	2.03	0.07	2.56
Fish	plains topminnow	Fundulus sciadicus	12611	0.25	0.24	4.31	0	4.8
Fish	pugnose minnow	Opsopoeodus emiliae	5260	0.13	0.57	2.3	0	3
Fish	pumpkinseed	Lepomis gibbosus	3	0	0	0	0	0
Fish	quillback	Carpiodes cyprinus	6314	0.21	0.3	3.2	0	3.71
Fish	rainbow darter	Etheostoma caeruleum	7210	0.94	0.98	7	0	8.92
Fish	rainbow smelt	Osmerus mordax	730	0.14	0	0	0	0.14
Fish	rainbow trout	Oncorhynchus mykiss	367	5.99	0.27	14.44	0	20.7
Fish	red shiner	Cyprinella lutrensis	50213	0.03	0.1	1.75	0	1.88
Fish	redear sunfish	Lepomis microlophus	1120	0.54	1.34	9.82	0	11.7
Fish	redfin darter	Etheostoma whipplei	53	0	0	0	0	0
Fish	redfin shiner	Lythrurus umbratilis	41776	0.17	0.3	2.64	0.01	3.12
Fish	redspot chub	Nocomis asper	805	0	0	0.99	0	0.99
Fish	redspotted sunfish	Lepomis miniatus	7173	0.99	1.06	5.76	0	7.81
Fish	ribbon shiner	Lythrurus fumeus	4846	0.14	0.62	1.55	0	2.31

Appendix C, Continued.

Fish	river carpsucker	Carpiodes carpio	6732	0.22	0.4	3.09	0.03	3.74
Fish	river darter	Percina shumardi	1030	0.1	0.1	1.36	0	1.56
Fish	river redhorse	Moxostoma carinatum	2230	0.18	1.12	6.32	0	7.62
Fish	river shiner	Notropis blennius	1445	0.28	0.42	0.97	0.28	1.95
Fish	rock bass	Ambloplites rupestris	2445	0.12	1.1	2.99	0	4.21
Fish	rosyface shiner	Notropis rubellus	4432	0.77	1.06	7.51	0	9.34
Fish	Sabine shiner	Notropis sabinae	37	0	0	0	0	0
Fish	saddleback darter	Percina vigil	1684	0.06	1.13	2.55	0	3.74
Fish	sand shiner	Notropis stramineus	21416	0.09	0.18	2.52	0.04	2.83
Fish	sauger	Stizostedion canadense	2184	0.09	0.14	6.27	0.09	6.59
Fish	scaly sand darter	Ammocrypta vivax	699	0.14	0.14	6.58	0	6.86
Fish	shadow bass	Ambloplites ariommus	5180	0.83	1.06	5.04	0	6.93
Fish	shoal chub	Macrhybopsis hyostoma	1928	0.05	0	0.83	0.1	0.98
Fish	shorthead redhorse	Moxostoma macrolepidotum	7670	0.59	0.69	5.33	0	6.61
Fish	shortnose gar	Lepisosteus platostomus	5314	0.24	0.4	3.11	0.04	3.79
Fish	shovelnose sturgeon	Scaphirhynchus platorynchus	1245	0.16	0	0.16	0.16	0.48
Fish	sicklefin chub	Macrhybopsis meeki	821	0.12	0	0	0.24	0.36
Fish	silver carp	Hypophthalmichthys molitrix	972	0.1	0	0	0.21	0.31
Fish	silver chub	Macrhybopsis storeriana	2331	0.43	0	2.87	0.09	3.39
Fish	silver lamprey	Ichthyomyzon unicuspis	228	0	0	0	0	0
Fish	silver redhorse	Moxostoma anisurum	2788	0.18	1.11	5.6	0	6.89
Fish	silverband shiner	Notropis shumardi	649	0.15	0	0	0	0.15
Fish	silverjaw minnow	Notropis buccatus	1147	0	0	4.18	0	4.18
Fish	skipjack herring	Alosa chrysochloris	1443	0.28	0.21	6.31	0.14	6.94
Fish	slender madtom	Noturus exilis	10388	0.32	0.54	5.09	0	5.95
Fish	slenderhead darter	Percina phoxocephala	3786	0.08	0.63	3.65	0	4.36
Fish	slim minnow	Pimephales tenellus	664	0.15	0.75	7.23	0	8.13
Fish	slough darter	Etheostoma gracile	10890	0.09	0.28	2.34	0	2.71
Fish	smallmouth bass	Micropterus dolomieu	7710	0.66	0.86	6.54	0	8.06
Fish	smallmouth buffalo	Ictiobus bubalus	5891	0.19	0.49	3.04	0.03	3.75
Fish	southern brook lamprey	Ichthyomyzon gagei	2165	0.09	0.37	5.59	0	6.05
Fish	southern redbelly dace	Phoxinus erythrogaster	44432	0.63	0.54	8.42	0.05	9.64
Fish	speckled darter	Etheostoma stigmaeum	5611	0.12	0.57	1.62	0	2.31
Fish	spotfin shiner	Cyprinella spiloptera	1865	0.16	1.61	1.72	0	3.49
Fish	spottail shiner	Notropis hudsonius	356	0	0	0	0	0
Fish	spotted bass	Micropterus punctulatus	9075	0.11	0.4	2.62	0	3.13
Fish	spotted gar	Lepisosteus oculatus	5393	0.11	0.57	1.61	0	2.29
Fish	spotted sucker	Minytrema melanops	6404	0.12	0.5	1.5	0	2.12
Fish	stargazing darter	Percina uranidea	71	2.82	0	2.82	0	5.64
Fish	starhead topminnow	Fundulus dispar	213	1.41	0	3.76	0	5.17
Fish	steelcolor shiner	Cyprinella whipplei	1519	0.2	0.53	4.61	0	5.34
Fish	stippled darter	Etheostoma punctulatum	30831	0.58	0.55	6.52	0.07	7.72
Fish	stonecat	Noturus flavus	4841	0.25	0.58	3.31	0.04	4.18
Fish	striped bass	Morone saxatilis	384	0.26	0	0	0	0.26
Fish	striped mullet	Mugil cephalus	240	0	0	0	0	0
Fish	striped shiner	Luxilus chrysocephalus	14753	0.84	1.02	7.28	0	9.14
Fish	sturgeon chub	Macrhybopsis gelida	751	0.13	0	0	0.27	0.4
Fish	suckermouth minnow	Phenacobius mirabilis	14316	0.08	0.31	2.63	0.01	3.03
Fish	swamp darter	Etheostoma fusiforme	1	0	0	0	0	0

Appendix C, Continued.

Fish	tadpole madtom	Noturus gyrinus	10043	0.09	0.31	2.57	0	2.97
Fish	taillight shiner	Notropis maculatus	147	0	0	2.72	0	2.72
Fish	telescope shiner	Notropis telescopus	3181	1.85	1.32	11.03	0	14.2
Fish	threadfin shad	Dorosoma petenense	228	0	0	3.95	0	3.95
Fish	Topeka shiner	Notropis topeka	5922	0.03	0.02	1.45	0	1.5
Fish	trout-perch	Percopsis omiscomaycus	2614	0.34	0.54	2.1	0.08	3.06
Fish	walleye	Stizostedion vitreum	3047	0.92	0.66	6.5	0	8.08
Fish	warmouth	Chaenobryttus gulosus	11734	0.66	0.64	5.4	0	6.7
Fish	wedgespot shiner	Notropis greenei	2709	0.3	1.62	8.97	0	10.89
Fish	weed shiner	Notropis texanus	4905	0.14	0.61	1.49	0	2.24
Fish	western mosquitofish	Gambusia affinis	30802	0.13	0.35	2.88	0.02	3.38
Fish	western sand darter	Ammocrypta clara	948	0.11	0.11	4.11	0	4.33
Fish	western silvery minnow	Hybognathus argyritis	2902	0.21	0.28	1.14	0.28	1.91
Fish	white bass	Morone chrysops	2754	0.07	0.04	4.03	0.07	4.21
Fish	white crappie	Pomoxis annularis	11394	0.14	0.41	2.95	0.03	3.53
Fish	white sucker	Catostomus commersoni	87887	0.26	0.23	4.57	0.03	5.09
Fish	whitetail shiner	Cyprinella galactura	1496	0.4	1.27	15.78	0	17.45
Fish	yellow bass	Morone mississippiensis	522	0	0	0	0	0
Fish	yellow bullhead	Ameiurus natalis	29807	0.4	0.5	3.87	0.01	4.78
Fish	yellow perch	Perca flavescens	3	0	0	0	0	0
Fish	yoke darter	Etheostoma juliae	703	0.28	1.28	5.69	0	7.25
Mussel	Arkansas brokenray	Lampsilis reeveiana reeveiana	1482	1.42	1.96	9.45	0	12.83
Mussel	Asian clam	Corbicula fluminea	8639	0.28	0.75	3.38	0	4.41
Mussel	bankclimber	Plectomerus dombeyanus	504	0.2	0.2	2.18	0	2.58
Mussel	black sandshell	Ligumia recta	2360	1.14	1.19	8.47	0	10.8
Mussel	bleedingtooth mussel	Venustaconcha pleasi	3311	1.42	0.97	9.94	0	12.33
Mussel	bleufer	Potamilus purpuratus	6236	0.13	0.61	3.82	0	4.56
Mussel	butterfly	Ellipsaria lineolata	1270	0.24	0.55	7.48	0	8.27
Mussel	creeper	Strophitus undulatus	30294	0.15	0.45	3.04	0.02	3.66
Mussel	Curtis pearlymussel	Epioblasma florentina curtisii	442	0.45	0.9	17.42	0	18.77
Mussel	cylindrical papershell	Anodontoides ferussacianus	1807	0	0.17	2.16	0	2.33
Mussel	deertoe	Truncilla truncata	3052	0.29	0.29	8.62	0	9.2
Mussel	ebonyshell	Fusconaia ebena	239	0.84	0.42	7.95	0	9.21
Mussel	elephantear	Elliptio crassidens	820	0.24	0.37	2.93	0	3.54
Mussel	elktoe	Alasmidonta marginata	3893	0.23	1.16	7.27	0	8.66
Mussel	ellipse	Venustaconcha ellipsiformis	9014	0.13	0.38	3.61	0	4.12
Mussel	fat pocketbook	Potamilus capax	3	0	0	0	0	0
Mussel	fatmucket	Lampsilis siliquoidea	97455	0.31	0.36	5.01	0.03	5.71
Mussel	fawnsfoot	Truncilla donaciformis	1739	0.17	0.17	11.27	0	11.61
Mussel	flat floater	Anodonta suborbiculata	5938	0.17	0.39	2.86	0	3.42
Mussel	flutedshell	Lasmigona costata	4216	0.36	1.16	7.54	0	9.06
Mussel	fragile papershell	Leptodea fragilis	11572	0.17	0.67	3.21	0	4.05
Mussel	giant floater	Pyganodon grandis	103962	0.26	0.31	4.57	0.03	5.17
Mussel	hickorynut	Obovaria olivaria	164	0	0	0	0	0
Mussel	Higgins eye	Lampsilis higginsii	19	0	0	0	0	0
Mussel	lilliput	Toxolasma parvus	25671	0.18	0.41	3.1	0	3.69
Mussel	little spectaclecase	Villosa lienosa	18656	0.5	0.55	9.32	0.05	10.42
Mussel	mapleleaf	Quadrula quadrula	10131	0.16	0.44	2.7	0	3.3

Appendix C, Continued.

Mussel	monkeyface	Quadrula metanevra	2119	0.33	1.13	4.96	0	6.42
Mussel	mucket	Actinonaias ligamentina	2933	0.14	1.09	7.36	0	8.59
Mussel	Neosho mucket	Lampsilis rafinesqueana	614	0	0.16	4.23	0	4.39
Mussel	northern brokenray	Lampsilis reeveiana brittsi	5829	0.19	0.5	4.25	0	4.94
Mussel	Ouachita kidneyshell	Ptychobranchus occidentalis	14755	0.48	0.64	5.7	0.01	6.83
Mussel	Ozark brokenray	Lampsilis reeveiana brevicula	4507	1.07	0.8	8.85	0	10.72
Mussel	Ozark pigtoe	Fusconaia ozarkensis	2502	1.32	1.4	9.03	0	11.75
Mussel	paper pondshell	Utterbackia imbecillis	31650	0.17	0.31	3.24	0.02	3.74
Mussel	pimpleback	Quadrula pustulosa	7097	0.2	0.46	4.18	0	4.84
Mussel	pink heelsplitter	Potamilus alatus	5665	0.21	0.55	3.62	0	4.38
Mussel	pink mucket	Lampsilis abrupta	778	0.39	0.13	6.04	0	6.56
Mussel	pink papershell	Potamilus ohiensis	5124	0.23	0.16	3.4	0	3.79
Mussel	pistolgrip	Tritogonia verrucosa	7561	0.2	0.73	4.52	0	5.45
Mussel	plain pocketbook	Lampsilis cardium	10768	0.25	0.72	5.09	0	6.06
Mussel	pondhorn	Uniomerus tetralasmus	12184	0.08	0.34	2.81	0.03	3.26
Mussel	pondmussel	Ligumia subrostrata	99975	0.28	0.29	4.62	0.03	5.22
Mussel	purple lilliput	Toxolasma lividus	1453	0.28	0.76	8.4	0	9.44
Mussel	purple wartyback	Cyclonaias tuberculata	1325	0.3	0.98	8.3	0	9.58
Mussel	rabbitsfoot	Quadrula cylindrica cylindrica	507	0.39	0.79	24.46	0	25.64
Mussel	rainbow	Villosa iris	5088	1.32	1.16	8.59	0	11.07
Mussel	rock pocketbook	Arcidens confragosus	1944	0.15	0.98	3.03	0	4.16
Mussel	round pigtoe	Pleurobema sintoxia	2842	0.32	1.2	7.64	0	9.16
Mussel	salamander mussel	Simpsonaias ambigua	348	0.57	0	5.46	0	6.03
Mussel	scaleshell	Leptodea leptodon	770	0.26	0.39	1.56	0	2.21
Mussel	sheepnose	Plethobasus cyphyus	650	0.31	0.46	2.62	0	3.39
Mussel	slippershell mussel	Alasmidonta viridis	6535	0.54	0.7	5.39	0.03	6.66
Mussel	snuffbox	Epioblasma triquetra	572	0.35	0.17	5.94	0	6.46
Mussel	southern hickorynut	Obovaria jacksoniana	186	0	0	6.45	0	6.45
Mussel	spectaclecase	Cumberlandia monodonta	838	0.24	1.31	3.22	0	4.77
Mussel	spike	Elliptio dilatata	3848	0.26	0.96	6.19	0	7.41
Mussel	Texas lilliput	Toxolasma texasensis	450	0	0	1.33	0	1.33
Mussel	threehorn wartyback	Obliquaria reflexa	5972	0.15	0.62	3.48	0	4.25
Mussel	threeridge	Amblema plicata	10926	0.17	0.6	3.45	0	4.22
Mussel	Wabash pigtoe	Fusconaia flava	8328	0.19	0.89	4.07	0	5.15
Mussel	wartyback	Quadrula nodulata	2875	0.03	0.87	2.75	0	3.65
Mussel	washboard	Megalonaias nervosa	2104	0.38	0.95	4.52	0	5.85
Mussel	western fanshell	Cyprogenia aberti	855	0.23	0.47	16.14	0	16.84
Mussel	white heelsplitter	Lasmigona complanata	10416	0.17	0.4	3.11	0	3.68
Mussel	yellow sandshell	Lampsilis teres	7956	0.2	0.75	3.26	0	4.21
Mussel	zebra mussel	Dreissena polymorpha	539	0	0	1.67	0	1.67
Crayfish	belted crayfish	Orconectes harrisonii	330	0	0.3	1.21	0	1.51
Crayfish	Big Creek crayfish	Orconectes peruncus	419	0	1.43	7.88	0	9.31
Crayfish	Cajun dwarf crayfish	Cambarellus puer	10	0	0	0	0	0
Crayfish	coldwater crayfish	Orconectes eupunctus	47	46.81	0	4.26	0	51.07
Crayfish	devil crayfish	Cambarus diogenes	35151	0.35	0.44	7.54	0	8.33
Crayfish	digger crayfish	Fallicambarus fodiens	4	0	0	0	0	0
Crayfish	freckled crayfish	Cambarus maculatus	988	0.3	0.4	7.39	0	8.09
Crayfish	golden crayfish	Orconectes luteus	15263	0.24	0.57	4.97	0.01	5.79
Crayfish	grassland crayfish	Procambarus gracilis	22087	0.04	0.04	1.05	0.01	1.14

Appendix C, Continued.

Crayfish	gray-speckled crayfish	Orconectes palmeri	5404	0.11	0.57	1.17	0	1.85
Crayfish	Hubbs' crayfish	Cambarus hubbsi	928	3.02	1.94	8.94	0	13.9
Crayfish	longpincered crayfish	Orconectes longidigitus	746	0.27	1.34	6.84	0	8.45
Crayfish	Mammoth Spring crayfish	Orconectes marchandi	7	0	0	0	0	0
Crayfish	Meek's crayfish	Orconectes meeki	78	0	0	25.64	0	25.64
Crayfish	Neosho midget crayfish	Orconectes macrus	721	0	0	1.25	0	1.25
Crayfish	Ozark crayfish	Orconectes ozarkae	9892	2.01	1.26	16.63	0.21	20.11
Crayfish	papershell crayfish	Orconectes immunis	30430	0.04	0.13	1.17	0.02	1.36
Crayfish	red swamp crayfish	Procambarus clarkii	4645	0.13	0.65	1.1	0	1.88
Crayfish	ringed crayfish	Orconectes neglectus	10917	0.92	0.69	6.43	0.21	8.25
Crayfish	saddlebacked crayfish	Orconectes medius	4957	0.08	0.46	10.01	0	10.55
Crayfish	shield crayfish	Faxonella clypeata	599	0	5.18	7.35	0	12.53
Crayfish	shrimp crayfish	Orconectes lancifer	59	0	0	0	0	0
Crayfish	Shufeldt's dwarf crayfish	Cambarellus shufeldtii	4599	0.13	0.65	1.26	0	2.04
Crayfish	spothanded crayfish	Orconectes punctimanus	36298	0.76	0.82	10.41	0.06	12.05
Crayfish	St. Francis River crayfish	Orconectes quadruncus	2004	0.35	2.05	11.53	0	13.93
Crayfish	vernal crayfish	Procambarus viaeviridis	3	0	33.33	33.33	0	66.66
Crayfish	virile crayfish	Orconectes virilis	57057	0.12	0.21	2.43	0.01	2.77
Crayfish	white river crayfish	Procambarus acutus	59	0	0	11.86	0	11.86
Crayfish	Williams' crayfish	Orconectes williamsi	184	0	0	12.5	0	12.5
Crayfish	woodland crayfish	Orconectes hylas	1270	0.08	1.18	8.82	0	10.08

APPENDIX D

Same as Appendix C, except this table is sorted, in ascending order, by percent of predicted range in public land (Public), then by taxon, and finally by common name.

TAXON	COMMON	SCIENTIFIC	TOTAL	GAP1	GAP2	GAP3	GAP4	PUBLIC
Fish	alligator gar	Atractosteus spatula	300	0	0	0	0	0
Fish	central mudminnow	Umbra limi	6	0	0	0	0	0
Fish	golden topminnow	Fundulus chrysotus	20	0	0	0	0	0
Fish	inland silverside	Menidia beryllina	90	0	0	0	0	0
Fish	Neosho madtom	Noturus placidus	3	0	0	0	0	0
Fish	plains killifish	Fundulus zebrinus	11	0	0	0	0	0
Fish	pumpkinseed	Lepomis gibbosus	3	0	0	0	0	0
Fish	redfin darter	Etheostoma whipplei	53	0	0	0	0	0
Fish	Sabine shiner	Notropis sabinae	37	0	0	0	0	0
Fish	silver lamprey	Ichthyomyzon unicuspis	228	0	0	0	0	0
Fish	spottail shiner	Notropis hudsonius	356	0	0	0	0	0
Fish	striped mullet	Mugil cephalus	240	0	0	0	0	0
Fish	swamp darter	Etheostoma fusiforme	1	0	0	0	0	0
Fish	yellow bass	Morone mississippiensis	522	0	0	0	0	0
Fish	yellow perch	Perca flavescens	3	0	0	0	0	0
Mussel	fat pocketbook	Potamilus capax	3	0	0	0	0	0
Mussel	hickorynut	Obovaria olivaria	164	0	0	0	0	0
Mussel	Higgins eye	Lampsilis higginsii	19	0	0	0	0	0
Crayfish	Cajun dwarf crayfish	Cambarellus puer	10	0	0	0	0	0
Crayfish	digger crayfish	Fallicambarus fodiens	4	0	0	0	0	0
Crayfish	Mammoth Spring crayfish	Orconectes marchandi	7	0	0	0	0	0
Crayfish	shrimp crayfish	Orconectes lancifer	59	0	0	0	0	0
Fish	rainbow smelt	Osmerus mordax	730	0.14	0	0	0	0.14
Fish	channel shiner	Notropis wickliffi	676	0.15	0	0	0	0.15
Fish	silverband shiner	Notropis shumardi	649	0.15	0	0	0	0.15
Fish	striped bass	Morone saxatilis	384	0.26	0	0	0	0.26
Fish	grass carp	Ctenopharyngodon idella	972	0.1	0	0	0.21	0.31
Fish	lake sturgeon	Acipenser fulvescens	962	0.1	0	0	0.21	0.31
Fish	silver carp	Hypophthalmichthys molitrix	972	0.1	0	0	0.21	0.31
Fish	pallid sturgeon	Scaphirhynchus albus	858	0.12	0	0	0.23	0.35
Fish	sicklefin chub	Macrhybopsis meeki	821	0.12	0	0	0.24	0.36
Fish	sturgeon chub	Macrhybopsis gelida	751	0.13	0	0	0.27	0.4
Fish	shovelnose sturgeon	Scaphirhynchus platorynchus	1245	0.16	0	0.16	0.16	0.48
Fish	ironcolor shiner	Notropis chalybaeus	1588	0	0	0.5	0	0.5
Fish	burbot	Lota lota	323	0	0	0	0.62	0.62
Fish	Arkansas darter	Etheostoma cragini	2926	0.07	0	0.65	0	0.72
Fish	cardinal shiner	Luxilus cardinalis	3695	0.05	0	0.89	0	0.94
Fish	bluntface shiner	Cyprinella camura	423	0	0	0.95	0	0.95
Fish	shoal chub	Macrhybopsis hyostoma	1928	0.05	0	0.83	0.1	0.98
Fish	redspot chub	Nocomis asper	805	0	0	0.99	0	0.99
Fish	bighead carp	Hypophthalmichthys nobilis	1197	0.08	0	0.75	0.17	1
Fish	blue catfish	Ictalurus furcatus	1519	0.07	0	0.92	0.13	1.12
Crayfish	grassland crayfish	Procambarus gracilis	22087	0.04	0.04	1.05	0.01	1.14
Fish	Alabama shad	Alosa alabamae	842	0.12	0	1.07	0	1.19

Appendix D, Continued.

Fish	channel darter	Percina copelandi	333	0	0	1.2	0	1.2
Fish	flathead chub	Platygobio gracilis	1071	0.09	0	0.93	0.19	1.21
Crayfish	Neosho midget crayfish	Orconectes macrus	721	0	0	1.25	0	1.25
Mussel	Texas lilliput	Toxolasma texasensis	450	0	0	1.33	0	1.33
Crayfish	papershell crayfish	Orconectes immunis	30430	0.04	0.13	1.17	0.02	1.36
Fish	mud darter	Etheostoma asprigene	915	0.11	0.11	1.2	0	1.42
Fish	Topeka shiner	Notropis topeka	5922	0.03	0.02	1.45	0	1.5
Crayfish	belted crayfish	Orconectes harrisonii	330	0	0.3	1.21	0	1.51
Fish	bigmouth shiner	Notropis dorsalis	29776	0.05	0.18	1.3	0.03	1.56
Fish	river darter	Percina shumardi	1030	0.1	0.1	1.36	0	1.56
Fish	brassy minnow	Hybognathus hankinsoni	1582	0	0	1.64	0	1.64
Mussel	zebra mussel	Dreissena polymorpha	539	0	0	1.67	0	1.67
Fish	lake chubsucker	Erimyzon sucetta	2768	0.14	0.4	1.19	0	1.73
Fish	fathead minnow	Pimephales promelas	49796	0.04	0.12	1.66	0.02	1.84
Crayfish	gray-speckled crayfish	Orconectes palmeri	5404	0.11	0.57	1.17	0	1.85
Fish	red shiner	Cyprinella lutrensis	50213	0.03	0.1	1.75	0	1.88
Crayfish	red swamp crayfish	Procambarus clarkii	4645	0.13	0.65	1.1	0	1.88
Fish	western silvery minnow	Hybognathus argyritis	2902	0.21	0.28	1.14	0.28	1.91
Fish	river shiner	Notropis blennius	1445	0.28	0.42	0.97	0.28	1.95
Fish	common shiner	Luxilus cornutus	17076	0.03	0.08	1.8	0.04	1.95
Fish	Johnny darter	Etheostoma nigrum	32799	0.05	0.1	1.8	0	1.95
Crayfish	Shufeldt's dwarf crayfish	Cambarellus shufeldtii	4599	0.13	0.65	1.26	0	2.04
Fish	spotted sucker	Minytrema melanops	6404	0.12	0.5	1.5	0	2.12
Fish	banded pygmy sunfish	Elassoma zonatum	5249	0.08	0.57	1.51	0	2.16
Fish	golden shiner	Notemigonus crysoleucas	26905	0.05	0.25	1.87	0.02	2.19
Mussel	scaleshell	Leptodea leptodon	770	0.26	0.39	1.56	0	2.21
Fish	weed shiner	Notropis texanus	4905	0.14	0.61	1.49	0	2.24
Fish	spotted gar	Lepisosteus oculatus	5393	0.11	0.57	1.61	0	2.29
Fish	ribbon shiner	Lythrurus fumeus	4846	0.14	0.62	1.55	0	2.31
Fish	speckled darter	Etheostoma stigmaeum	5611	0.12	0.57	1.62	0	2.31
Mussel	cylindrical papershell	Anodontoides ferussacianus	1807	0	0.17	2.16	0	2.33
Fish	bluntnose darter	Etheostoma chlorosomum	7605	0.08	0.39	1.92	0	2.39
Fish	dusky darter	Percina sciera	5114	0.12	0.61	1.76	0	2.49
Fish	blackstripe topminnow	Fundulus notatus	17850	0.07	0.27	2.2	0	2.54
Fish	cypress darter	Etheostoma proeliare	6286	0.11	0.49	1.94	0	2.54
Fish	plains minnow	Hybognathus placitus	2998	0.33	0.13	2.03	0.07	2.56
Fish	cypress minnow	Hybognathus hayi	156	0	0	2.56	0	2.56
Mussel	bankclimber	Plectomerus dombeyanus	504	0.2	0.2	2.18	0	2.58
Fish	bullhead minnow	Pimephales vigilax	6860	0.09	0.48	2.03	0	2.6
Fish	northern pike	Esox lucius	339	0	0	2.65	0	2.65
Fish	blue sucker	Cycleptus elongatus	1827	0.11	0.05	2.41	0.11	2.68
Fish	slough darter	Etheostoma gracile	10890	0.09	0.28	2.34	0	2.71
Fish	harlequin darter	Etheostoma histrio	147	0	0	2.72	0	2.72
Fish	taillight shiner	Notropis maculatus	147	0	0	2.72	0	2.72
Crayfish	virile crayfish	Orconectes virilis	57057	0.12	0.21	2.43	0.01	2.77
Fish	sand shiner	Notropis stramineus	21416	0.09	0.18	2.52	0.04	2.83
Fish	blackside darter	Percina maculata	5602	0.09	0.54	2.21	0	2.84
Fish	orangespotted sunfish	Lepomis humilis	24535	0.09	0.26	2.49	0.02	2.86
Fish	flier	Centrarchus macropterus	1624	0.37	0.68	1.91	0	2.96

Appendix D, Continued.

Fish	tadpole madtom	Noturus gyrinus	10043	0.09	0.31	2.57	0	2.97
Fish	pugnose minnow	Opsopoeodus emiliae	5260	0.13	0.57	2.3	0	3
Fish	suckermouth minnow	Phenacobius mirabilis	14316	0.08	0.31	2.63	0.01	3.03
Fish	blacktail shiner	Cyprinella venusta	5393	0.17	0.57	2.32	0	3.06
Fish	trout-perch	Percopsis omiscomaycus	2614	0.34	0.54	2.1	0.08	3.06
Fish	redfin shiner	Lythrurus umbratilis	41776	0.17	0.3	2.64	0.01	3.12
Fish	spotted bass	Micropterus punctulatus	9075	0.11	0.4	2.62	0	3.13
Mussel	pondhorn	Uniomerus tetralasmus	12184	0.08	0.34	2.81	0.03	3.26
Fish	emerald shiner	Notropis atherinoides	5789	0.14	0.43	2.66	0.03	3.26
Fish	bluntnose minnow	Pimephales notatus	77977	0.2	0.27	2.82	0.01	3.3
Mussel	mapleleaf	Quadrula quadrula	10131	0.16	0.44	2.7	0	3.3
Fish	largemouth bass	Micropterus salmoides	46762	0.2	0.33	2.81	0.02	3.36
Fish	western mosquitofish	Gambusia affinis	30802	0.13	0.35	2.88	0.02	3.38
Fish	silver chub	Macrhybopsis storeriana	2331	0.43	0	2.87	0.09	3.39
Mussel	sheepnose	Plethobasus cyphyus	650	0.31	0.46	2.62	0	3.39
Fish	black bullhead	Ameiurus melas	80937	0.09	0.21	3.11	0.01	3.42
Mussel	flat floater	Anodonta suborbiculata	5938	0.17	0.39	2.86	0	3.42
Fish	ghost shiner	Notropis buchanani	3575	0.03	0.08	3.27	0.06	3.44
Fish	spotfin shiner	Cyprinella spiloptera	1865	0.16	1.61	1.72	0	3.49
Fish	white crappie	Pomoxis annularis	11394	0.14	0.41	2.95	0.03	3.53
Mussel	elephantear	Elliptio crassidens	820	0.24	0.37	2.93	0	3.54
Mussel	wartyback	Quadrula nodulata	2875	0.03	0.87	2.75	0	3.65
Mussel	creeper	Strophitus undulatus	30294	0.15	0.45	3.04	0.02	3.66
Mussel	white heelsplitter	Lasmigona complanata	10416	0.17	0.4	3.11	0	3.68
Mussel	lilliput	Toxolasma parvus	25671	0.18	0.41	3.1	0	3.69
Fish	quillback	Carpiodes cyprinus	6314	0.21	0.3	3.2	0	3.71
Fish	common carp	Cyprinus carpio	24949	0.21	0.39	3.13	0.01	3.74
Fish	river carpsucker	Carpiodes carpio	6732	0.22	0.4	3.09	0.03	3.74
Fish	saddleback darter	Percina vigil	1684	0.06	1.13	2.55	0	3.74
Mussel	paper pondshell	Utterbackia imbecillis	31650	0.17	0.31	3.24	0.02	3.74
Fish	smallmouth buffalo	Ictiobus bubalus	5891	0.19	0.49	3.04	0.03	3.75
Fish	pallid shiner	Notropis amnis	1091	0.09	0.09	3.57	0	3.75
Fish	shortnose gar	Lepisosteus platostomus	5314	0.24	0.4	3.11	0.04	3.79
Mussel	pink papershell	Potamilus ohiensis	5124	0.23	0.16	3.4	0	3.79
Fish	mimic shiner	Notropis volucellus	2785	0.11	0.83	2.91	0	3.85
Fish	threadfin shad	Dorosoma petenense	228	0	0	3.95	0	3.95
Fish	longnose gar	Lepisosteus osseus	10437	0.2	0.63	3.15	0.02	4
Mussel	fragile papershell	Leptodea fragilis	11572	0.17	0.67	3.21	0	4.05
Fish	least darter	Etheostoma microperca	2073	0.05	0.05	3.96	0	4.06
Fish	goldeye	Hiodon alosoides	2646	0.34	0.26	3.51	0	4.11
Mussel	ellipse	Venustaconcha ellipsiformis	9014	0.13	0.38	3.61	0	4.12
Fish	bowfin	Amia calva	1252	0.16	0.24	3.75	0	4.15
Mussel	rock pocketbook	Arcidens confragosus	1944	0.15	0.98	3.03	0	4.16
Fish	silverjaw minnow	Notropis buccatus	1147	0	0	4.18	0	4.18
Fish	stonecat	Noturus flavus	4841	0.25	0.58	3.31	0.04	4.18
Mussel	yellow sandshell	Lampsilis teres	7956	0.2	0.75	3.26	0	4.21
Fish	rock bass	Ambloplites rupestris	2445	0.12	1.1	2.99	0	4.21
Fish	white bass	Morone chrysops	2754	0.07	0.04	4.03	0.07	4.21
Mussel	threeridge	Amblema plicata	10926	0.17	0.6	3.45	0	4.22

Appendix D, Continued.

Fish	blacknose shiner	Notropis heterolepis	1695	0.24	0.06	3.95	0	4.25
Mussel	threehorn wartyback	Obliquaria reflexa	5972	0.15	0.62	3.48	0	4.25
Fish	brook silverside	Labidesthes sicculus	14392	0.28	0.44	3.61	0	4.33
Fish	western sand darter	Ammocrypta clara	948	0.11	0.11	4.11	0	4.33
Fish	crystal darter	Crystallaria asprella	870	0.11	0.11	4.14	0	4.36
Fish	slenderhead darter	Percina phoxocephala	3786	0.08	0.63	3.65	0	4.36
Mussel	pink heelsplitter	Potamilus alatus	5665	0.21	0.55	3.62	0	4.38
Mussel	Neosho mucket	Lampsilis rafinesqueana	614	0	0.16	4.23	0	4.39
Mussel	Asian clam	Corbicula fluminea	8639	0.28	0.75	3.38	0	4.41
Fish	flathead catfish	Pylodictis olivaris	6626	0.21	0.5	3.73	0.03	4.47
Fish	orangethroat darter	Etheostoma spectabile	72510	0.23	0.26	3.99	0.04	4.52
Fish	gizzard shad	Dorosoma cepedianum	13567	0.37	0.61	3.55	0.01	4.54
Mussel	bleufer	Potamilus purpuratus	6236	0.13	0.61	3.82	0	4.56
Fish	channel catfish	Ictalurus punctatus	10624	0.23	0.59	3.77	0.02	4.61
Mussel	spectaclecase	Cumberlandia monodonta	838	0.24	1.31	3.22	0	4.77
Fish	yellow bullhead	Ameiurus natalis	29807	0.4	0.5	3.87	0.01	4.78
Fish	plains topminnow	Fundulus sciadicus	12611	0.25	0.24	4.31	0	4.8
Mussel	pimpleback	Quadrula pustulosa	7097	0.2	0.46	4.18	0	4.84
Fish	freshwater drum	Aplodinotus grunniens	7464	0.2	0.66	4.01	0.03	4.9
Fish	bigmouth buffalo	Ictiobus cyprinellus	8205	0.21	0.49	4.2	0.02	4.92
Mussel	northern brokenray	Lampsilis reeveiana brittsi	5829	0.19	0.5	4.25	0	4.94
Fish	Niangua darter	Etheostoma nianguae	827	0	0	4.96	0	4.96
Fish	white sucker	Catostomus commersoni	87887	0.26	0.23	4.57	0.03	5.09
Mussel	Wabash pigtoe	Fusconaia flava	8328	0.19	0.89	4.07	0	5.15
Fish	starhead topminnow	Fundulus dispar	213	1.41	0	3.76	0	5.17
Mussel	giant floater	Pyganodon grandis	103962	0.26	0.31	4.57	0.03	5.17
Mussel	pondmussel	Ligumia subrostrata	99975	0.28	0.29	4.62	0.03	5.22
Fish	Missouri saddled darter	Etheostoma tetrazonum	2335	0.13	1.16	3.94	0	5.23
Fish	blackspotted topminnow	Fundulus olivaceus	15781	0.5	0.74	4.07	0	5.31
Fish	steelcolor shiner	Cyprinella whipplei	1519	0.2	0.53	4.61	0	5.34
Fish	logperch	Percina caprodes	9406	0.31	0.43	4.61	0	5.35
Fish	black buffalo	Ictiobus niger	3758	0.11	0.56	4.71	0	5.38
Fish	bluegill	Lepomis macrochirus	107924	0.31	0.35	4.7	0.03	5.39
Fish	green sunfish	Lepomis cyanellus	107840	0.31	0.35	4.7	0.03	5.39
Mussel	pistolgrip	Tritogonia verrucosa	7561	0.2	0.73	4.52	0	5.45
Fish	bluestripe darter	Percina cymatotaenia	832	0.12	2.76	2.64	0	5.52
Fish	gravel chub	Erimystax x-punctatus	2158	0.14	1.07	4.31	0	5.52
Fish	creek chub	Semotilus atromaculatus	98853	0.32	0.34	4.85	0.03	5.54
Fish	stargazing darter	Percina uranidea	71	2.82	0	2.82	0	5.64
Fish	central stoneroller	Campostoma anomalum	100268	0.33	0.34	4.95	0.03	5.65
Mussel	fatmucket	Lampsilis siliquoidea	97455	0.31	0.36	5.01	0.03	5.71
Crayfish	golden crayfish	Orconectes luteus	15263	0.24	0.57	4.97	0.01	5.79
Fish	mottled sculpin	Cottus bairdi	5060	0.26	0.69	4.84	0	5.79
Mussel	washboard	Megalonaias nervosa	2104	0.38	0.95	4.52	0	5.85
Fish	slender madtom	Noturus exilis	10388	0.32	0.54	5.09	0	5.95
Fish	brindled madtom	Noturus miurus	738	0	0.14	5.83	0	5.97
Mussel	salamander mussel	Simpsonaias ambigua	348	0.57	0	5.46	0	6.03
Fish	southern brook lamprey	Ichthyomyzon gagei	2165	0.09	0.37	5.59	0	6.05
Mussel	plain pocketbook	Lampsilis cardium	10768	0.25	0.72	5.09	0	6.06

Appendix D, Continued.

Fish	black crappie	Pomoxis nigromaculatus	3472	0.14	0.69	5.18	0.06	6.07
Mussel	monkeyface	Quadrula metanevra	2119	0.33	1.13	4.96	0	6.42
Mussel	southern hickorynut	Obovaria jacksoniana	186	0	0	6.45	0	6.45
Fish	goldfish	Carassius auratus	31	0	3.23	3.23	0	6.46
Mussel	snuffbox	Epioblasma triquetra	572	0.35	0.17	5.94	0	6.46
Fish	longear sunfish	Lepomis megalotis	33275	0.46	0.56	5.44	0.01	6.47
Mussel	pink mucket	Lampsilis abrupta	778	0.39	0.13	6.04	0	6.56
Fish	sauger	Stizostedion canadense	2184	0.09	0.14	6.27	0.09	6.59
Fish	shorthead redhorse	Moxostoma macrolepidotum	7670	0.59	0.69	5.33	0	6.61
Fish	highfin carpsucker	Carpiodes velifer	1496	0.2	1.8	4.61	0	6.61
Mussel	slippershell mussel	Alasmidonta viridis	6535	0.54	0.7	5.39	0.03	6.66
Fish	northern brook lamprey	Ichthyomyzon fossor	539	0.56	4.45	1.67	0	6.68
Fish	warmouth	Chaenobryttus gulosus	11734	0.66	0.64	5.4	0	6.7
Mussel	Ouachita kidneyshell	Ptychobranchus occidentalis	14755	0.48	0.64	5.7	0.01	6.83
Fish	paddlefish	Polyodon spathula	2349	0.17	0.13	6.47	0.09	6.86
Fish	golden redhorse	Moxostoma erythrurum	6897	0.51	0.61	5.74	0	6.86
Fish	scaly sand darter	Ammocrypta vivax	699	0.14	0.14	6.58	0	6.86
Fish	silver redhorse	Moxostoma anisurum	2788	0.18	1.11	5.6	0	6.89
Fish	shadow bass	Ambloplites ariommus	5180	0.83	1.06	5.04	0	6.93
Fish	skipjack herring	Alosa chrysochloris	1443	0.28	0.21	6.31	0.14	6.94
Fish	chestnut lamprey	Ichthyomyzon castaneus	3250	0.22	0.49	6.25	0.06	7.02
Fish	mooneye	Hiodon tergisus	1358	0.29	0.74	6.11	0	7.14
Fish	yoke darter	Etheostoma juliae	703	0.28	1.28	5.69	0	7.25
Fish	bigeye shiner	Notropis boops	5804	0.62	0.78	5.93	0	7.33
Mussel	spike	Elliptio dilatata	3848	0.26	0.96	6.19	0	7.41
Fish	river redhorse	Moxostoma carinatum	2230	0.18	1.12	6.32	0	7.62
Fish	stippled darter	Etheostoma punctulatum	30831	0.58	0.55	6.52	0.07	7.72
Fish	redspotted sunfish	Lepomis miniatus	7173	0.99	1.06	5.76	0	7.81
Fish	largescale stoneroller	Campostoma oligolepis	10429	0.84	0.76	6.26	0	7.86
Fish	bleeding shiner	Luxilus zonatus	7949	0.81	0.79	6.37	0	7.97
Fish	freckled madtom	Noturus nocturnus	1741	0.29	0.17	7.58	0	8.04
Fish	northern studfish	Fundulus catenatus	10274	0.85	0.76	6.43	0	8.04
Fish	smallmouth bass	Micropterus dolomieu	7710	0.66	0.86	6.54	0	8.06
Fish	walleye	Stizostedion vitreum	3047	0.92	0.66	6.5	0	8.08
Crayfish	freckled crayfish	Cambarus maculatus	988	0.3	0.4	7.39	0	8.09
Fish	slim minnow	Pimephales tenellus	664	0.15	0.75	7.23	0	8.13
Fish	pirate perch	Aphredoderus sayanus	11285	0.12	0.76	7.35	0	8.23
Crayfish	ringed crayfish	Orconectes neglectus	10917	0.92	0.69	6.43	0.21	8.25
Mussel	butterfly	Ellipsaria lineolata	1270	0.24	0.55	7.48	0	8.27
Crayfish	devil crayfish	Cambarus diogenes	35151	0.35	0.44	7.54	0	8.33
Crayfish	longpincered crayfish	Orconectes longidigitus	746	0.27	1.34	6.84	0	8.45
Fish	fantail darter	Etheostoma flabellare	54113	0.46	0.51	7.49	0.02	8.48
Fish	Ozark minnow	Notropis nubilus	20247	0.71	0.84	6.95	0	8.5
Fish	American eel	Anguilla rostrata	2365	1.18	0.93	6.34	0.08	8.53
Fish	Ozark bass	Ambloplites constellatus	1190	0.17	0.92	7.48	0	8.57
Mussel	mucket	Actinonaias ligamentina	2933	0.14	1.09	7.36	0	8.59
Mussel	elktoe	Alasmidonta marginata	3893	0.23	1.16	7.27	0	8.66
Fish	Mississippi silvery minnow	Hybognathus nuchalis	1013	0.2	0.2	8.39	0	8.79

Appendix D, Continued.

Fish	black redhorse	Moxostoma duquesnei	5570	0.66	0.9	7.29	0	8.85
Fish	rainbow darter	Etheostoma caeruleum	7210	0.94	0.98	7	0	8.92
Mussel	flutedshell	Lasmigona costata	4216	0.36	1.16	7.54	0	9.06
Fish	northern hog sucker	Hypentelium nigricans	5433	0.66	0.94	7.47	0	9.07
Fish	mountain madtom	Noturus eleutherus	11	0	0	9.09	0	9.09
Fish	striped shiner	Luxilus chrysocephalus	14753	0.84	1.02	7.28	0	9.14
Mussel	round pigtoe	Pleurobema sintoxia	2842	0.32	1.2	7.64	0	9.16
Fish	banded sculpin	Cottus carolinae	13286	0.84	1.02	7.32	0	9.18
Fish	grass pickerel	Esox americanus	22544	0.47	0.73	7.94	0.05	9.19
Mussel	deertoe	Truncilla truncata	3052	0.29	0.29	8.62	0	9.2
Mussel	ebonyshell	Fusconaia ebena	239	0.84	0.42	7.95	0	9.21
Crayfish	Big Creek crayfish	Orconectes peruncus	419	0	1.43	7.88	0	9.31
Fish	rosyface shiner	Notropis rubellus	4432	0.77	1.06	7.51	0	9.34
Mussel	purple lilliput	Toxolasma lividus	1453	0.28	0.76	8.4	0	9.44
Fish	banded darter	Etheostoma zonale	3224	1.05	1.15	7.35	0	9.55
Mussel	purple wartyback	Cyclonaias tuberculata	1325	0.3	0.98	8.3	0	9.58
Fish	greenside darter	Etheostoma blennioides	5017	0.72	1	7.87	0	9.59
Fish	southern redbelly dace	Phoxinus erythrogaster	44432	0.63	0.54	8.42	0.05	9.64
Fish	longnose darter	Percina nasuta	169	0	0	10.06	0	10.06
Crayfish	woodland crayfish	Orconectes hylas	1270	0.08	1.18	8.82	0	10.08
Mussel	little spectaclecase	Villosa lienosa	18656	0.5	0.55	9.32	0.05	10.42
Crayfish	saddlebacked crayfish	Orconectes medius	4957	0.08	0.46	10.01	0	10.55
Mussel	Ozark brokenray	Lampsilis reeveiana brevicula	4507	1.07	0.8	8.85	0	10.72
Fish	hornyhead chub	Nocomis biguttatus	25486	0.87	0.77	9.13	0.02	10.79
Mussel	black sandshell	Ligumia recta	2360	1.14	1.19	8.47	0	10.8
Fish	wedgespot shiner	Notropis greenei	2709	0.3	1.62	8.97	0	10.89
Fish	least brook lamprey	Lampetra aepyptera	4525	1.02	1.35	8.66	0.04	11.07
Mussel	rainbow	Villosa iris	5088	1.32	1.16	8.59	0	11.07
Fish	goldstripe darter	Etheostoma parvipinne	9	0	0	11.11	0	11.11
Mussel	fawnsfoot	Truncilla donaciformis	1739	0.17	0.17	11.27	0	11.61
Fish	duskystripe shiner	Luxilus pilsbryi	7467	1.31	1	9	0.31	11.62
Fish	bigeye chub	Notropis amblops	3169	1.14	0.85	9.69	0	11.68
Fish	redear sunfish	Lepomis microlophus	1120	0.54	1.34	9.82	0	11.7
Mussel	Ozark pigtoe	Fusconaia ozarkensis	2502	1.32	1.4	9.03	0	11.75
Crayfish	white river crayfish	Procambarus acutus	59	0	0	11.86	0	11.86
Crayfish	spothanded crayfish	Orconectes punctimanus	36298	0.76	0.82	10.41	0.06	12.05
Mussel	bleedingtooth mussel	Venustaconcha pleasi	3311	1.42	0.97	9.94	0	12.33
Crayfish	Williams' crayfish	Orconectes williamsi	184	0	0	12.5	0	12.5
Crayfish	shield crayfish	Faxonella clypeata	599	0	5.18	7.35	0	12.53
Mussel	Arkansas brokenray	Lampsilis reeveiana reeveiana	1482	1.42	1.96	9.45	0	12.83
Fish	gilt darter	Percina evides	1285	0.23	2.1	10.66	0	12.99
Fish	creek chubsucker	Erimyzon oblongus	22744	0.87	1.11	11.35	0	13.33
Crayfish	Hubbs' crayfish	Cambarus hubbsi	928	3.02	1.94	8.94	0	13.9
Crayfish	St. Francis River crayfish	Orconectes quadruncus	2004	0.35	2.05	11.53	0	13.93
Fish	telescope shiner	Notropis telescopus	3181	1.85	1.32	11.03	0	14.2
Fish	Ozark sculpin	Cottus hypselurus	1980	1.67	1.72	12.32	0	15.71
Mussel	western fanshell	Cyprogenia aberti	855	0.23	0.47	16.14	0	16.84
Fish	whitetail shiner	Cyprinella galactura	1496	0.4	1.27	15.78	0	17.45

Appendix D, Continued.

Mussel	Curtis pearlymussel	Epioblasma florentina curtisii	442	0.45	0.9	17.42	0	18.77
Fish	checkered madtom	Noturus flavater	665	1.65	1.8	16.24	0	19.69
Crayfish	Ozark crayfish	Orconectes ozarkae	9892	2.01	1.26	16.63	0.21	20.11
Fish	rainbow trout	Oncorhynchus mykiss	367	5.99	0.27	14.44	0	20.7
Fish	Ozark chub	Erimystax harryi	1022	0.39	1.76	19.96	0	22.11
Fish	brook darter	Etheostoma burri	1903	1.05	1.21	20.7	0	22.96
Fish	Current darter	Etheostoma uniporum	6847	1.87	1.36	19.92	0	23.15
Fish	Ozark madtom	Noturus albater	1173	2.3	3.41	19.01	0	24.72
Fish	Arkansas saddled darter	Etheostoma euzonum	266	0.75	0.75	23.68	0	25.18
Fish	brown trout	Salmo trutta	130	0	0.77	24.62	0	25.39
Fish	Ozark shiner	Notropis ozarcanus	488	2.05	1.64	21.93	0	25.62
Mussel	rabbitsfoot	Quadrula cylindrica cylindrica	507	0.39	0.79	24.46	0	25.64
Crayfish	Meek's crayfish	Orconectes meeki	78	0	0	25.64	0	25.64
Fish	chain pickerel	Esox niger	1081	4.63	3.89	25.44	0	33.96
Fish	American brook lamprey	Lampetra appendix	209	0.96	1.44	42.11	0	44.51
Fish	brown bullhead	Ameiurus nebulosus	68	0	39.71	8.82	0	48.53
Crayfish	coldwater crayfish	Orconectes eupunctus	47	46.81	0	4.26	0	51.07
Fish	bantam sunfish	Lepomis symmetricus	59	1.69	42.37	15.25	0	59.31
Crayfish	vernal crayfish	Procambarus viaeviridis	3	0	33.33	33.33	0	66.66
Fish	dollar sunfish	Lepomis marginatus	4	0	0	75	0	75

APPENDIX E

Stewardship statistics for all fish, mussel, and crayfish species in Missouri. This table shows the number of watersheds in which each species is predicted to occur (Total) and how many of these distinct occurrences are currently captured in existing public lands (Public). Results are further broken down by GAP stewardship category (GAP 1-4). This table is sorted by taxonomic group and common name.

TAXON	COMMON	SCIENTIFIC	TOTAL	GAP1	GAP2	GAP3	GAP4	PUBLIC
Fish	Alabama shad	Alosa alabamae	36	1	0	3	0	4
	alligator gar	Atractosteus spatula	17	0	0	0	0	0
	American brook lamprey	Lampetra appendix	9	1	4	7	0	12
	American eel	Anguilla rostrata	116	6	6	23	1	36
	Arkansas darter	Etheostoma cragini	9	1	0	4	0	5
	Arkansas saddled darter	Etheostoma euzonum	15	1	3	5	0	9
	banded darter	Etheostoma zonale	142	9	13	51	0	73
	banded pygmy sunfish	Elassoma zonatum	40	3	1	19	0	23
	banded sculpin	Cottus carolinae	192	18	21	113	0	152
	bantam sunfish	Lepomis symmetricus	3	1	1	3	0	5
	bigeye chub	Notropis amblops	126	10	16	58	0	84
	bigeye shiner	Notropis boops	181	10	18	73	0	101
	bighead carp	Hypophthalmichthys nobilis	65	1	0	1	1	3
	bigmouth buffalo	Ictiobus cyprinellus	370	8	13	82	1	104
	bigmouth shiner	Notropis dorsalis	270	6	8	93	2	109
	black buffalo	Ictiobus niger	147	3	5	29	0	37
	black bullhead	Ameiurus melas	522	28	26	241	2	297
	black crappie	Pomoxis nigromaculatus	169	4	10	31	1	46
	black redhorse	Moxostoma duquesnei	218	12	20	84	0	116
	blacknose shiner	Notropis heterolepis	56	3	1	17	0	21
	blackside darter	Percina maculata	114	3	1	32	0	36
	blackspotted topminnow	Fundulus olivaceus	236	23	22	123	0	168
	blackstripe topminnow	Fundulus notatus	227	8	6	87	0	101
	blacktail shiner	Cyprinella venusta	45	5	2	18	0	25
	bleeding shiner	Luxilus zonatus	153	13	18	83	0	114
	blue catfish	Ictalurus furcatus	78	1	0	3	1	5
	blue sucker	Cycleptus elongatus	93	2	1	10	1	14
	bluegill	Lepomis macrochirus	584	49	37	291	5	382
	bluestripe darter	Percina cymatotaenia	34	2	3	10	0	15
	bluntface shiner	Cyprinella camura	14	0	0	2	0	2
	bluntnose darter	Etheostoma chlorosomum	87	4	1	39	0	44
	bluntnose minnow	Pimephales notatus	531	41	33	274	2	350
	bowfin	Amia calva	70	1	1	14	0	16
	brassy minnow	Hybognathus hankinsoni	37	0	0	10	0	10
	brindled madtom	Noturus miurus	38	0	1	12	0	13
	brook darter	Etheostoma burri	10	3	3	10	0	16
	brook silverside	Labidesthes sicculus	330	15	14	115	0	144
	brown bullhead	Ameiurus nebulosus	6	0	1	2	0	3
	brown trout	Salmo trutta	16	0	1	9	0	10
	bullhead minnow	Pimephales vigilax	135	5	2	34	0	41
	burbot	Lota lota	23	0	0	0	1	1

Appendix E, Continued.

Fish	cardinal shiner	Luxilus cardinalis	18	1	0	5	0	6
	central mudminnow	Umbra limi	1	0	0	0	0	0
	central stoneroller	Campostoma anomalum	515	44	34	276	4	358
	chain pickerel	Esox niger	34	6	10	24	0	40
	channel catfish	Ictalurus punctatus	505	12	16	116	1	145
	channel darter	Percina copelandi	12	0	0	2	0	2
	channel shiner	Notropis wickliffi	33	1	0	0	0	1
	checkered madtom	Noturus flavater	32	4	6	12	0	22
	chestnut lamprey	Ichthyomyzon castaneus	167	5	8	40	1	54
	common carp	Cyprinus carpio	563	20	23	174	1	218
	common shiner	Luxilus cornutus	89	3	3	43	1	50
	creek chub	Semotilus atromaculatus	510	41	36	272	4	353
	creek chubsucker	Erimyzon oblongus	101	19	22	73	0	114
	crystal darter	Crystallaria asprella	33	1	1	12	0	14
	Current darter	Etheostoma uniporum	27	5	8	22	0	35
	cypress darter	Etheostoma proeliare	42	5	1	23	0	29
	cypress minnow	Hybognathus hayi	5	0	0	3	0	3
	dollar sunfish	Lepomis marginatus	2	0	0	1	0	1
	dusky darter	Percina sciera	51	4	2	19	0	25
	duskystripe shiner	Luxilus pilsbryi	33	8	4	26	3	41
	emerald shiner	Notropis atherinoides	261	5	3	43	1	52
	fantail darter	Etheostoma flabellare	284	36	29	171	1	237
	fathead minnow	Pimephales promelas	373	8	10	131	2	151
	flathead catfish	Pylodictis olivaris	355	7	9	65	1	82
	flathead chub	Platygobio gracilis	60	1	0	2	1	4
	flier	Centrarchus macropterus	22	4	1	10	0	15
	freckled madtom	Noturus nocturnus	77	4	3	27	0	34
	freshwater drum	Aplodinotus grunniens	347	6	13	71	1	91
	ghost shiner	Notropis buchanani	196	2	1	28	1	32
	gilt darter	Percina evides	52	2	8	20	0	30
	gizzard shad	Dorosoma cepedianum	474	18	21	115	1	155
	golden redhorse	Moxostoma erythrurum	310	9	15	99	0	123
	golden shiner	Notemigonus crysoleucas	427	9	14	146	1	170
	golden topminnow	Fundulus chrysotus	1	0	0	0	0	0
	goldeye	Hiodon alosoides	140	2	2	26	0	30
	goldfish	Carassius auratus	19	0	1	1	0	2
	goldstripe darter	Etheostoma parvipinne	1	0	0	1	0	1
	grass carp	Ctenopharyngodon idella	57	1	0	0	1	2
	grass pickerel	Esox americanus	105	20	12	77	2	111
	gravel chub	Erimystax x-punctatus	95	2	3	26	0	31
	green sunfish	Lepomis cyanellus	583	49	37	290	5	381
	greenside darter	Etheostoma blennioides	199	12	20	81	0	113
	harlequin darter	Etheostoma histrio	4	0	0	3	0	3
	highfin carpsucker	Carpiodes velifer	50	2	3	16	0	21
	hornyhead chub	Nocomis biguttatus	216	30	25	137	2	194
	inland silverside	Menidia beryllina	6	0	0	0	0	0
	ironcolor shiner	Notropis chalybaeus	11	0	0	2	0	2
	Johnny darter	Etheostoma nigrum	334	8	7	119	0	134
	lake chubsucker	Erimyzon sucetta	26	2	1	10	0	13

Appendix E, Continued.

Fish	lake sturgeon	Acipenser fulvescens	54	1	0	0	1	2
	largemouth bass	Micropterus salmoides	578	30	31	244	2	307
	largescale stoneroller	Campostoma oligolepis	208	20	22	111	0	153
	least brook lamprey	Lampetra aepyptera	84	13	16	59	1	89
	least darter	Etheostoma microperca	40	1	1	18	0	20
	logperch	Percina caprodes	328	10	12	117	0	139
	longear sunfish	Lepomis megalotis	309	30	28	166	2	226
	longnose darter	Percina nasuta	10	0	0	3	0	3
	longnose gar	Lepisosteus osseus	340	11	13	71	1	96
	mimic shiner	Notropis volucellus	79	2	3	29	0	34
	Mississippi silvery minnow	Hybognathus nuchalis	48	1	2	12	0	15
	Missouri saddled darter	Etheostoma tetrazonum	84	3	6	32	0	41
	mooneye	Hiodon tergisus	55	3	3	14	0	20
	mottled sculpin	Cottus bairdi	64	5	6	37	0	48
	mountain madtom	Noturus eleutherus	2	0	0	1	0	1
	mud darter	Etheostoma asprigene	45	1	1	6	0	8
	muskellunge	Esox masquinongy	6	0	0	4	0	4
	Neosho madtom	Noturus placidus	1	0	0	0	0	0
	Niangua darter	Etheostoma nianguae	16	0	0	9	0	9
	northern brook lamprey	Ichthyomyzon fossor	20	3	4	7	0	14
	northern hog sucker	Hypentelium nigricans	223	11	21	82	0	114
	northern pike	Esox lucius	10	0	0	4	0	4
	northern studfish	Fundulus catenatus	216	20	21	115	0	156
	orangespotted sunfish	Lepomis humilis	483	11	16	150	2	179
	orangethroat darter	Etheostoma spectabile	355	33	20	201	4	258
	Ozark bass	Ambloplites constellatus	41	2	4	21	0	27
	Ozark cavefish	Amblyopsis rosae	12	0	0	1	0	1
	Ozark chub	Erimystax harryi	57	3	12	25	0	40
	Ozark madtom	Noturus albater	42	8	9	27	0	44
	Ozark minnow	Notropis nubilus	202	27	24	127	0	178
	Ozark sculpin	Cottus hypselurus	99	8	16	41	0	65
	Ozark shiner	Notropis ozarcanus	30	4	7	12	0	23
	paddlefish	Polyodon spathula	119	4	4	20	1	29
	pallid shiner	Notropis amnis	48	1	1	14	0	16
	pallid sturgeon	Scaphirhynchus albus	51	1	0	0	1	2
	pirate perch	Aphredoderus sayanus	63	6	4	33	0	43
	plains killifish	Fundulus zebrinus	3	0	0	0	0	0
	plains minnow	Hybognathus placitus	186	3	1	20	1	25
	plains topminnow	Fundulus sciadicus	51	7	4	32	0	43
	pugnose minnow	Opsopoeodus emiliae	45	5	2	20	0	27
	pumpkinseed	Lepomis gibbosus	2	0	0	0	0	0
	quillback	Carpiodes cyprinus	277	6	4	57	0	67
	rainbow darter	Etheostoma caeruleum	176	17	22	94	0	133
	rainbow smelt	Osmerus mordax	44	1	0	0	0	1
	rainbow trout	Oncorhynchus mykiss	44	3	2	16	0	21
	red shiner	Cyprinella lutrensis	441	9	8	153	1	171
	redear sunfish	Lepomis microlophus	53	4	8	23	0	35
	redfin darter	Etheostoma whipplei	3	0	0	0	0	0
	redfin shiner	Lythrurus umbratilis	450	22	22	208	1	253

Appendix E, Continued.

Fish	redspot chub	Nocomis asper	16	0	0	2	0	2
	redspotted sunfish	Lepomis miniatus	71	12	7	40	0	59
	ribbon shiner	Lythrurus fumeus	33	5	1	15	0	21
	river carpsucker	Carpiodes carpio	372	7	6	64	1	78
	river darter	Percina shumardi	52	1	1	7	0	9
	river redhorse	Moxostoma carinatum	107	3	6	33	0	42
	river shiner	Notropis blennius	131	2	3	8	2	15
	rock bass	Ambloplites rupestris	76	3	6	29	0	38
	rosyface shiner	Notropis rubellus	200	10	19	72	0	101
	rudd	Scardinius erythrophthalmus	2	0	0	2	0	2
	Sabine shiner	Notropis sabinae	2	0	0	0	0	0
	saddleback darter	Percina vigil	40	1	1	13	0	15
	sand shiner	Notropis stramineus	429	9	8	138	2	157
	sauger	Stizostedion canadense	112	2	4	17	1	24
	scaly sand darter	Ammocrypta vivax	33	1	1	12	0	14
	shadow bass	Ambloplites ariommus	76	11	13	36	0	60
	shoal chub	Macrhybopsis hyostoma	99	1	0	7	1	9
	shorthead redhorse	Moxostoma macrolepidotum	385	14	20	100	0	134
	shortnose gar	Lepisosteus platostomus	290	5	5	50	1	61
	shovelnose sturgeon	Scaphirhynchus platorynchus	67	2	0	1	1	4
	sicklefin chub	Macrhybopsis meeki	50	1	0	0	1	2
	silver carp	Hypophthalmichthys molitrix	57	1	0	0	1	2
	silver chub	Macrhybopsis storeriana	173	3	0	17	1	21
	silver lamprey	Ichthyomyzon unicuspis	11	0	0	0	0	0
	silver redhorse	Moxostoma anisurum	114	5	9	41	0	55
	silverband shiner	Notropis shumardi	36	1	0	0	0	1
	silverjaw minnow	Notropis buccatus	36	0	0	13	0	13
	skipjack herring	Alosa chrysochloris	74	3	4	7	1	15
	slender madtom	Noturus exilis	280	17	18	117	0	152
	slenderhead darter	Percina phoxocephala	182	4	4	40	0	48
	slim minnow	Pimephales tenellus	33	1	3	10	0	14
	slough darter	Etheostoma gracile	79	5	1	41	0	47
	smallmouth bass	Micropterus dolomieu	268	12	22	105	0	139
	smallmouth buffalo	Ictiobus bubalus	286	4	5	53	1	63
	southern brook lamprey	Ichthyomyzon gagei	52	2	4	27	0	33
	southern cavefish	Typhlichthys subterraneus	15	2	3	6	0	11
	southern redbelly dace	Phoxinus erythrogaster	208	35	24	137	3	199
	speckled darter	Etheostoma stigmaeum	66	5	2	20	0	27
	spotfin shiner	Cyprinella spiloptera	83	3	6	17	0	26
	spottail shiner	Notropis hudsonius	20	0	0	0	0	0
	spotted bass	Micropterus punctulatus	238	7	5	67	0	79
	spotted gar	Lepisosteus oculatus	65	4	2	14	0	20
	spotted sucker	Minytrema melanops	91	6	3	29	0	38
	spring cavefish	Forbesichthys agassizii	1	0	0	0	0	0
	stargazing darter	Percina uranidea	4	1	0	1	0	2
	starhead topminnow	Fundulus dispar	9	1	0	5	0	6
	steelcolor shiner	Cyprinella whipplei	76	2	5	23	0	30
	stippled darter	Etheostoma punctulatum	123	21	10	85	3	119
	stonecat	Noturus flavus	257	5	6	45	1	57

Appendix E, Continued.

Fish	striped bass	Morone saxatilis	18	1	0	0	0	1
	striped mullet	Mugil cephalus	15	0	0	0	0	0
	striped shiner	Luxilus chrysocephalus	226	22	25	122	0	169
	sturgeon chub	Macrhybopsis gelida	47	1	0	0	1	2
	suckermouth minnow	Phenacobius mirabilis	430	5	8	108	1	122
	swamp darter	Etheostoma fusiforme	1	0	0	0	0	0
	tadpole madtom	Noturus gyrinus	181	8	2	67	0	77
	taillight shiner	Notropis maculatus	4	0	0	3	0	3
	telescope shiner	Notropis telescopus	83	14	15	54	0	83
	threadfin shad	Dorosoma petenense	13	0	0	1	0	1
	Topeka shiner	Notropis topeka	66	1	1	16	0	18
	trout-perch	Percopsis omiscomaycus	85	2	3	22	1	28
	walleye	Stizostedion vitreum	148	6	8	32	0	46
	warmouth	Chaenobryttus gulosus	191	15	6	81	0	102
	wedgespot shiner	Notropis greenei	113	7	18	49	0	74
	weed shiner	Notropis texanus	38	5	1	14	0	20
	western mosquitofish	Gambusia affinis	387	22	17	150	1	190
	western sand darter	Ammocrypta clara	46	1	1	11	0	13
	western silvery minnow	Hybognathus argyritis	116	3	3	17	2	25
	white bass	Morone chrysops	140	2	1	22	1	26
	white crappie	Pomoxis annularis	461	9	14	102	2	127
	white sucker	Catostomus commersoni	475	32	28	252	4	316
	whitetail shiner	Cyprinella galactura	67	4	13	33	0	50
	yellow bass	Morone mississippiensis	29	0	0	0	0	0
	yellow bullhead	Ameiurus natalis	458	30	29	206	2	267
	yellow perch	Perca flavescens	1	0	0	0	0	0
	yoke darter	Etheostoma juliae	29	2	3	12	0	17
Mussel	Arkansas brokenray	Lampsilis reeveiana reeveiana	51	7	10	29	0	46
	Asian clam	Corbicula fluminea	264	11	13	61	0	85
	bankclimber	Plectomerus dombeyanus	22	1	1	6	0	8
	black sandshell	Ligumia recta	106	5	10	34	0	49
	bleedingtooth mussel	Venustaconcha pleasi	81	11	13	43	0	67
	bleufer	Potamilus purpuratus	102	6	10	37	0	53
	butterfly	Ellipsaria lineolata	54	2	5	11	0	18
	creeper	Strophitus undulatus	499	20	30	203	1	254
	Curtis pearlymussel	Epioblasma florentina curtisii	34	1	4	13	0	18
	cylindrical papershell	Anodontoides ferussacianus	65	0	1	17	0	18
	deertoe	Truncilla truncata	150	4	8	47	0	59
	ebonyshell	Fusconaia ebena	16	1	1	5	0	7
	elephantear	Elliptio crassidens	32	1	1	7	0	9
	elktoe	Alasmidonta marginata	176	8	16	63	0	87
	ellipse	Venustaconcha ellipsiformis	158	5	9	80	0	94
	fat pocketbook	Potamilus capax	1	0	0	0	0	0
	fatmucket	Lampsilis siliquoidea	506	44	36	276	4	360
	fawnsfoot	Truncilla donaciformis	83	2	4	28	0	34
	flat floater	Anodonta suborbiculata	294	3	6	60	0	69
	flutedshell	Lasmigona costata	200	9	19	70	0	98
	fragile papershell	Leptodea fragilis	415	11	14	104	0	129
	giant floater	Pyganodon grandis	563	43	33	278	4	358

Appendix E, Continued.

Mussel	hickorynut	Obovaria olivaria	6	0	0	0	0	0
	Higgins eye	Lampsilis higginsii	2	0	0	0	0	0
	lilliput	Toxolasma parvus	482	20	24	189	1	234
	little spectaclecase	Villosa lienosa	112	17	17	83	2	119
	mapleleaf	Quadrula quadrula	355	7	7	80	0	94
	monkeyface	Quadrula metanevra	94	2	5	25	0	32
	mucket	Actinonaias ligamentina	164	3	11	44	0	58
	Neosho mucket	Lampsilis rafinesqueana	32	0	1	7	0	8
	northern brokenray	Lampsilis reeveiana brittsi	72	5	7	45	0	57
	Ouachita kidneyshell	Ptychobranchus occidentalis	110	16	14	77	1	108
	Ozark brokenray	Lampsilis reeveiana brevicula	103	12	14	56	0	82
	Ozark pigtoe	Fusconaia ozarkensis	108	9	13	39	0	61
	paper pondshell	Utterbackia imbecillis	502	14	25	206	1	246
	pimpleback	Quadrula pustulosa	330	6	10	81	0	97
	pink heelsplitter	Potamilus alatus	295	5	6	66	0	77
	pink mucket	Lampsilis abrupta	33	2	1	11	0	14
	pink papershell	Potamilus ohiensis	269	4	3	58	0	65
	pistolgrip	Tritogonia verrucosa	359	7	14	86	0	107
	plain pocketbook	Lampsilis cardium	430	14	25	134	0	173
	pondhorn	Uniomerus tetralasmus	322	4	11	99	2	116
	pondmussel	Ligumia subrostrata	514	40	32	276	4	352
	purple lilliput	Toxolasma lividus	71	3	7	29	0	39
	purple wartyback	Cyclonaias tuberculata	57	3	5	15	0	23
	rabbitsfoot	Quadrula cylindrica cylindrica	30	1	6	11	0	18
	rainbow	Villosa iris	103	16	18	65	0	99
	rock pocketbook	Arcidens confragosus	53	2	2	15	0	19
	round pigtoe	Pleurobema sintoxia	151	6	12	44	0	62
	salamander mussel	Simpsonaias ambigua	12	1	0	5	0	6
	scaleshell	Leptodea leptodon	25	1	1	4	0	6
	sheepnose	Plethobasus cyphyus	20	1	1	7	0	9
	slippershell mussel	Alasmidonta viridis	105	9	12	64	1	86
	snuffbox	Epioblasma triquetra	23	1	2	10	0	13
	southern hickorynut	Obovaria jacksoniana	14	0	0	4	0	4
	spectaclecase	Cumberlandia monodonta	27	1	2	6	0	9
	spike	Elliptio dilatata	189	7	14	56	0	77
	Texas lilliput	Toxolasma texasensis	7	0	0	3	0	3
	threehorn wartyback	Obliquaria reflexa	108	5	6	35	0	46
	threeridge	Amblema plicata	359	10	14	89	0	113
	Wabash pigtoe	Fusconaia flava	404	9	17	106	0	132
	wartyback	Quadrula nodulata	117	1	3	22	0	26
	washboard	Megalonaias nervosa	101	3	2	24	0	29
	western fanshell	Cyprogenia aberti	45	1	6	19	0	26
	white heelsplitter	Lasmigona complanata	325	9	8	82	0	99
	yellow sandshell	Lampsilis teres	395	8	9	85	0	102
	zebra mussel	Dreissena polymorpha	27	0	0	3	0	3
Crayfish	belted crayfish	Orconectes harrisonii	7	0	1	4	0	5
	Big Creek crayfish	Orconectes peruncus	7	0	2	5	0	7
	bristly cave crayfish	Cambarus setosus	16	0	0	1	0	1
	Cajun dwarf crayfish	Cambarellus puer	3	0	0	0	0	0

Appendix E, Continued.

Crayfish	coldwater crayfish	Orconectes eupunctus	6	3	0	2	0	5
	devil crayfish	Cambarus diogenes	456	23	23	175	0	221
	digger crayfish	Fallicambarus fodiens	2	0	0	0	0	0
	freckled crayfish	Cambarus maculatus	16	1	2	13	0	16
	golden crayfish	Orconectes luteus	262	18	21	127	1	167
	grassland crayfish	Procambarus gracilis	324	5	7	86	1	99
	gray-speckled crayfish	Orconectes palmeri	35	4	1	13	0	18
	Hubbs' crayfish	Cambarus hubbsi	49	5	7	26	0	38
	longpincered crayfish	Orconectes longidigitus	31	2	4	16	0	22
	Mammoth Spring crayfish	Orconectes marchandi	1	0	0	0	0	0
	Meek's crayfish	Orconectes meeki	4	0	0	3	0	3
	Neosho midget crayfish	Orconectes macrus	16	0	0	3	0	3
	Ozark crayfish	Orconectes ozarkae	59	14	12	45	3	74
	papershell crayfish	Orconectes immunis	313	6	9	103	1	119
	red swamp crayfish	Procambarus clarkii	26	4	1	12	0	17
	ringed crayfish	Orconectes neglectus	49	9	4	30	3	46
	saddlebacked crayfish	Orconectes medius	16	3	3	15	0	21
	Salem cave crayfish	Cambarus hubrichti	11	4	1	4	0	9
	shield crayfish	Faxonella clypeata	11	0	1	8	0	9
	shrimp crayfish	Orconectes lancifer	2	0	0	0	0	0
	Shufeldt's dwarf crayfish	Cambarellus shufeldtii	26	4	1	13	0	18
	spothanded crayfish	Orconectes punctimanus	143	31	27	112	3	173
	St. Francis River crayfish	Orconectes quadruncus	7	3	3	7	0	13
	vernal crayfish	Procambarus viaeviridis	3	0	1	1	0	2
	virile crayfish	Orconectes virilis	483	24	23	233	2	282
	white river crayfish	Procambarus acutus	21	0	0	2	0	2
	Williams' crayfish	Orconectes williamsi	14	0	0	9	0	9
	woodland crayfish	Orconectes hylas	17	1	6	16	0	23

APPENDIX F

Same as Appendix E, except this table is sorted, in ascending order, by number of distinct occurrences captured within public land (Public) for each species, then by taxon, and finally by common name.

TAXON	COMMON	SCIENTIFIC	TOTAL	GAP1	GAP2	GAP3	GAP4	PUBLIC
Fish	alligator gar	Atractosteus spatula	17	0	0	0	0	0
	central mudminnow	Umbra limi	1	0	0	0	0	0
	golden topminnow	Fundulus chrysotus	1	0	0	0	0	0
	inland silverside	Menidia beryllina	6	0	0	0	0	0
	Neosho madtom	Noturus placidus	1	0	0	0	0	0
	plains killifish	Fundulus zebrinus	3	0	0	0	0	0
	pumpkinseed	Lepomis gibbosus	2	0	0	0	0	0
	redfin darter	Etheostoma whipplei	3	0	0	0	0	0
	Sabine shiner	Notropis sabinae	2	0	0	0	0	0
	silver lamprey	Ichthyomyzon unicuspis	11	0	0	0	0	0
	spottail shiner	Notropis hudsonius	20	0	0	0	0	0
	spring cavefish	Forbesichthys agassizii	1	0	0	0	0	0
	striped mullet	Mugil cephalus	15	0	0	0	0	0
	swamp darter	Etheostoma fusiforme	1	0	0	0	0	0
	yellow bass	Morone mississippiensis	29	0	0	0	0	0
	yellow perch	Perca flavescens	1	0	0	0	0	0
Mussel	fat pocketbook	Potamilus capax	1	0	0	0	0	0
	hickorynut	Obovaria olivaria	6	0	0	0	0	0
	Higgins eye	Lampsilis higginsii	2	0	0	0	0	0
Crayfish	Cajun dwarf crayfish	Cambarellus puer	3	0	0	0	0	0
	digger crayfish	Fallicambarus fodiens	2	0	0	0	0	0
	Mammoth Spring crayfish	Orconectes marchandi	1	0	0	0	0	0
	shrimp crayfish	Orconectes lancifer	2	0	0	0	0	0
Fish	burbot	Lota lota	23	0	0	0	1	1
	channel shiner	Notropis wickliffi	33	1	0	0	0	1
	dollar sunfish	Lepomis marginatus	2	0	0	1	0	1
	goldstripe darter	Etheostoma parvipinne	1	0	0	1	0	1
	mountain madtom	Noturus eleutherus	2	0	0	1	0	1
	Ozark cavefish	Amblyopsis rosae	12	0	0	1	0	1
	rainbow smelt	Osmerus mordax	44	1	0	0	0	1
	silverband shiner	Notropis shumardi	36	1	0	0	0	1
	striped bass	Morone saxatilis	18	1	0	0	0	1
	threadfin shad	Dorosoma petenense	13	0	0	1	0	1
Crayfish	bristly cave crayfish	Cambarus setosus	16	0	0	1	0	1
Fish	bluntface shiner	Cyprinella camura	14	0	0	2	0	2
	channel darter	Percina copelandi	12	0	0	2	0	2
	goldfish	Carassius auratus	19	0	1	1	0	2
	grass carp	Ctenopharyngodon idella	57	1	0	0	1	2
	ironcolor shiner	Notropis chalybaeus	11	0	0	2	0	2
	lake sturgeon	Acipenser fulvescens	54	1	0	0	1	2
	pallid sturgeon	Scaphirhynchus albus	51	1	0	0	1	2
	redspot chub	Nocomis asper	16	0	0	2	0	2
	rudd	Scardinius erythrophthalmus	2	0	0	2	0	2

Appendix F, Continued.

Fish	sicklefin chub	Macrhybopsis meeki	50	1	0	0	1	2
	silver carp	Hypophthalmichthys molitrix	57	1	0	0	1	2
	stargazing darter	Percina uranidea	4	1	0	1	0	2
	sturgeon chub	Macrhybopsis gelida	47	1	0	0	1	2
Crayfish	vernal crayfish	Procambarus viaeviridis	3	0	1	1	0	2
	white river crayfish	Procambarus acutus	21	0	0	2	0	2
Fish	bighead carp	Hypophthalmichthys nobilis	65	1	0	1	1	3
	brown bullhead	Ameiurus nebulosus	6	0	1	2	0	3
	cypress minnow	Hybognathus hayi	5	0	0	3	0	3
	harlequin darter	Etheostoma histrio	4	0	0	3	0	3
	longnose darter	Percina nasuta	10	0	0	3	0	3
	taillight shiner	Notropis maculatus	4	0	0	3	0	3
Mussel	Texas lilliput	Toxolasma texasensis	7	0	0	3	0	3
	zebra mussel	Dreissena polymorpha	27	0	0	3	0	3
Crayfish	Meek’s crayfish	Orconectes meeki	4	0	0	3	0	3
	Neosho midget crayfish	Orconectes macrus	16	0	0	3	0	3
Fish	Alabama shad	Alosa alabamae	36	1	0	3	0	4
	flathead chub	Platygobio gracilis	60	1	0	2	1	4
	muskellunge	Esox masquinongy	6	0	0	4	0	4
	northern pike	Esox lucius	10	0	0	4	0	4
	shovelnose sturgeon	Scaphirhynchus platorynchus	67	2	0	1	1	4
Mussel	southern hickorynut	Obovaria jacksoniana	14	0	0	4	0	4
Fish	Arkansas darter	Etheostoma cragini	9	1	0	4	0	5
	bantam sunfish	Lepomis symmetricus	3	1	1	3	0	5
	blue catfish	Ictalurus furcatus	78	1	0	3	1	5
Crayfish	belted crayfish	Orconectes harrisonii	7	0	1	4	0	5
	coldwater crayfish	Orconectes eupunctus	6	3	0	2	0	5
Fish	cardinal shiner	Luxilus cardinalis	18	1	0	5	0	6
	starhead topminnow	Fundulus dispar	9	1	0	5	0	6
Mussel	salamander mussel	Simpsonaias ambigua	12	1	0	5	0	6
	scaleshell	Leptodea leptodon	25	1	1	4	0	6
	ebonyshell	Fusconaia ebena	16	1	1	5	0	7
Crayfish	Big Creek crayfish	Orconectes peruncus	7	0	2	5	0	7
Fish	mud darter	Etheostoma asprigene	45	1	1	6	0	8
Mussel	bankclimber	Plectomerus dombeyanus	22	1	1	6	0	8
	Neosho mucket	Lampsilis rafinesqueana	32	0	1	7	0	8
Fish	Arkansas saddled darter	Etheostoma euzonum	15	1	3	5	0	9
	Niangua darter	Etheostoma nianguae	16	0	0	9	0	9
	river darter	Percina shumardi	52	1	1	7	0	9
	shoal chub	Macrhybopsis hyostoma	99	1	0	7	1	9
Mussel	elephantear	Elliptio crassidens	32	1	1	7	0	9
	sheepnose	Plethobasus cyphyus	20	1	1	7	0	9
	spectaclecase	Cumberlandia monodonta	27	1	2	6	0	9
Crayfish	Salem cave crayfish	Cambarus hubrichti	11	4	1	4	0	9
	shield crayfish	Faxonella clypeata	11	0	1	8	0	9
	Williams’ crayfish	Orconectes williamsi	14	0	0	9	0	9
Fish	brassy minnow	Hybognathus hankinsoni	37	0	0	10	0	10
	brown trout	Salmo trutta	16	0	1	9	0	10
	southern cavefish	Typhlichthys subterraneus	15	2	3	6	0	11

Appendix F, Continued.

Fish	American brook lamprey	Lampetra appendix	9	1	4	7	0	12
	brindled madtom	Noturus miurus	38	0	1	12	0	13
	lake chubsucker	Erimyzon sucetta	26	2	1	10	0	13
	silverjaw minnow	Notropis buccatus	36	0	0	13	0	13
	western sand darter	Ammocrypta clara	46	1	1	11	0	13
Mussel	snuffbox	Epioblasma triquetra	23	1	2	10	0	13
Crayfish	St. Francis River crayfish	Orconectes quadruncus	7	3	3	7	0	13
Fish	blue sucker	Cycleptus elongatus	93	2	1	10	1	14
	crystal darter	Crystallaria asprella	33	1	1	12	0	14
	northern brook lamprey	Ichthyomyzon fossor	20	3	4	7	0	14
	scaly sand darter	Ammocrypta vivax	33	1	1	12	0	14
	slim minnow	Pimephales tenellus	33	1	3	10	0	14
Mussel	pink mucket	Lampsilis abrupta	33	2	1	11	0	14
Fish	bluestripe darter	Percina cymatotaenia	34	2	3	10	0	15
	flier	Centrarchus macropterus	22	4	1	10	0	15
	Mississippi silvery minnow	Hybognathus nuchalis	48	1	2	12	0	15
	river shiner	Notropis blennius	131	2	3	8	2	15
	saddleback darter	Percina vigil	40	1	1	13	0	15
	skipjack herring	Alosa chrysochloris	74	3	4	7	1	15
	bowfin	Amia calva	70	1	1	14	0	16
	brook darter	Etheostoma burri	10	3	3	10	0	16
	pallid shiner	Notropis amnis	48	1	1	14	0	16
Crayfish	freckled crayfish	Cambarus maculatus	16	1	2	13	0	16
Fish	yoke darter	Etheostoma juliae	29	2	3	12	0	17
Crayfish	red swamp crayfish	Procambarus clarkii	26	4	1	12	0	17
Fish	Topeka shiner	Notropis topeka	66	1	1	16	0	18
Mussel	butterfly	Ellipsaria lineolata	54	2	5	11	0	18
	Curtis pearlymussel	Epioblasma florentina curtisii	34	1	4	13	0	18
	cylindrical papershell	Anodontoides ferussacianus	65	0	1	17	0	18
	rabbitsfoot	Quadrula cylindrica cylindrica	30	1	6	11	0	18
Crayfish	gray-speckled crayfish	Orconectes palmeri	35	4	1	13	0	18
	Shufeldt's dwarf crayfish	Cambarellus shufeldtii	26	4	1	13	0	18
Mussel	rock pocketbook	Arcidens confragosus	53	2	2	15	0	19
Fish	least darter	Etheostoma microperca	40	1	1	18	0	20
	mooneye	Hiodon tergisus	55	3	3	14	0	20
	spotted gar	Lepisosteus oculatus	65	4	2	14	0	20
	weed shiner	Notropis texanus	38	5	1	14	0	20
	blacknose shiner	Notropis heterolepis	56	3	1	17	0	21
	highfin carpsucker	Carpiodes velifer	50	2	3	16	0	21
	rainbow trout	Oncorhynchus mykiss	44	3	2	16	0	21
	ribbon shiner	Lythrurus fumeus	33	5	1	15	0	21
	silver chub	Macrhybopsis storeriana	173	3	0	17	1	21
Crayfish	saddlebacked crayfish	Orconectes medius	16	3	3	15	0	21
Fish	checkered madtom	Noturus flavater	32	4	6	12	0	22
Crayfish	longpincered crayfish	Orconectes longidigitus	31	2	4	16	0	22
Fish	banded pygmy sunfish	Elassoma zonatum	40	3	1	19	0	23
	Ozark shiner	Notropis ozarcanus	30	4	7	12	0	23
Mussel	purple wartyback	Cyclonaias tuberculata	57	3	5	15	0	23
Crayfish	woodland crayfish	Orconectes hylas	17	1	6	16	0	23

Appendix F, Continued.

Fish	sauger	Stizostedion canadense	112	2	4	17	1	24
	blacktail shiner	Cyprinella venusta	45	5	2	18	0	25
	dusky darter	Percina sciera	51	4	2	19	0	25
	plains minnow	Hybognathus placitus	186	3	1	20	1	25
	western silvery minnow	Hybognathus argyritis	116	3	3	17	2	25
	spotfin shiner	Cyprinella spiloptera	83	3	6	17	0	26
	white bass	Morone chrysops	140	2	1	22	1	26
Mussel	wartyback	Quadrula nodulata	117	1	3	22	0	26
	western fanshell	Cyprogenia aberti	45	1	6	19	0	26
Fish	Ozark bass	Ambloplites constellatus	41	2	4	21	0	27
	pugnose minnow	Opsopoeodus emiliae	45	5	2	20	0	27
	speckled darter	Etheostoma stigmaeum	66	5	2	20	0	27
	trout-perch	Percopsis omiscomaycus	85	2	3	22	1	28
	cypress darter	Etheostoma proeliare	42	5	1	23	0	29
	paddlefish	Polyodon spathula	119	4	4	20	1	29
Mussel	washboard	Megalonaias nervosa	101	3	2	24	0	29
Fish	gilt darter	Percina evides	52	2	8	20	0	30
	goldeye	Hiodon alosoides	140	2	2	26	0	30
	steelcolor shiner	Cyprinella whipplei	76	2	5	23	0	30
	gravel chub	Erimystax x-punctatus	95	2	3	26	0	31
	ghost shiner	Notropis buchanani	196	2	1	28	1	32
Mussel	monkeyface	Quadrula metanevra	94	2	5	25	0	32
Fish	southern brook lamprey	Ichthyomyzon gagei	52	2	4	27	0	33
	freckled madtom	Noturus nocturnus	77	4	3	27	0	34
	mimic shiner	Notropis volucellus	79	2	3	29	0	34
Mussel	fawnsfoot	Truncilla donaciformis	83	2	4	28	0	34
Fish	Current darter	Etheostoma uniporum	27	5	8	22	0	35
	redear sunfish	Lepomis microlophus	53	4	8	23	0	35
	American eel	Anguilla rostrata	116	6	6	23	1	36
	blackside darter	Percina maculata	114	3	1	32	0	36
	black buffalo	Ictiobus niger	147	3	5	29	0	37
	rock bass	Ambloplites rupestris	76	3	6	29	0	38
	spotted sucker	Minytrema melanops	91	6	3	29	0	38
Crayfish	Hubbs' crayfish	Cambarus hubbsi	49	5	7	26	0	38
Mussel	purple lilliput	Toxolasma lividus	71	3	7	29	0	39
Fish	chain pickerel	Esox niger	34	6	10	24	0	40
	Ozark chub	Erimystax harryi	57	3	12	25	0	40
	bullhead minnow	Pimephales vigilax	135	5	2	34	0	41
	duskystripe shiner	Luxilus pilsbryi	33	8	4	26	3	41
	Missouri saddled darter	Etheostoma tetrazonum	84	3	6	32	0	41
	river redhorse	Moxostoma carinatum	107	3	6	33	0	42
	pirate perch	Aphredoderus sayanus	63	6	4	33	0	43
	plains topminnow	Fundulus sciadicus	51	7	4	32	0	43
	bluntnose darter	Etheostoma chlorosomum	87	4	1	39	0	44
	Ozark madtom	Noturus albater	42	8	9	27	0	44
	black crappie	Pomoxis nigromaculatus	169	4	10	31	1	46
	walleye	Stizostedion vitreum	148	6	8	32	0	46
Mussel	Arkansas brokenray	Lampsilis reeveiana reeveiana	51	7	10	29	0	46
	threehorn wartyback	Obliquaria reflexa	108	5	6	35	0	46

Appendix F, Continued.

Crayfish	ringed crayfish	Orconectes neglectus	49	9	4	30	3	46
Fish	slough darter	Etheostoma gracile	79	5	1	41	0	47
	mottled sculpin	Cottus bairdi	64	5	6	37	0	48
	slenderhead darter	Percina phoxocephala	182	4	4	40	0	48
Mussel	black sandshell	Ligumia recta	106	5	10	34	0	49
Fish	common shiner	Luxilus cornutus	89	3	3	43	1	50
	whitetail shiner	Cyprinella galactura	67	4	13	33	0	50
	emerald shiner	Notropis atherinoides	261	5	3	43	1	52
Mussel	bleufer	Potamilus purpuratus	102	6	10	37	0	53
Fish	chestnut lamprey	Ichthyomyzon castaneus	167	5	8	40	1	54
	silver redhorse	Moxostoma anisurum	114	5	9	41	0	55
	stonecat	Noturus flavus	257	5	6	45	1	57
Mussel	northern brokenray	Lampsilis reeveiana brittsi	72	5	7	45	0	57
	mucket	Actinonaias ligamentina	164	3	11	44	0	58
Fish	redspotted sunfish	Lepomis miniatus	71	12	7	40	0	59
Mussel	deertoe	Truncilla truncata	150	4	8	47	0	59
Fish	shadow bass	Ambloplites ariommus	76	11	13	36	0	60
	shortnose gar	Lepisosteus platostomus	290	5	5	50	1	61
Mussel	Ozark pigtoe	Fusconaia ozarkensis	108	9	13	39	0	61
	round pigtoe	Pleurobema sintoxia	151	6	12	44	0	62
Fish	smallmouth buffalo	Ictiobus bubalus	286	4	5	53	1	63
	Ozark sculpin	Cottus hypselurus	99	8	16	41	0	65
Mussel	pink papershell	Potamilus ohiensis	269	4	3	58	0	65
Fish	quillback	Carpiodes cyprinus	277	6	4	57	0	67
Mussel	bleedingtooth mussel	Venustaconcha pleasi	81	11	13	43	0	67
	flat floater	Anodonta suborbiculata	294	3	6	60	0	69
Fish	banded darter	Etheostoma zonale	142	9	13	51	0	73
	wedgespot shiner	Notropis greenei	113	7	18	49	0	74
Crayfish	Ozark crayfish	Orconectes ozarkae	59	14	12	45	3	74
Fish	tadpole madtom	Noturus gyrinus	181	8	2	67	0	77
Mussel	pink heelsplitter	Potamilus alatus	295	5	6	66	0	77
	spike	Elliptio dilatata	189	7	14	56	0	77
Fish	river carpsucker	Carpiodes carpio	372	7	6	64	1	78
	spotted bass	Micropterus punctulatus	238	7	5	67	0	79
	flathead catfish	Pylodictis olivaris	355	7	9	65	1	82
Mussel	Ozark brokenray	Lampsilis reeveiana brevicula	103	12	14	56	0	82
Fish	telescope shiner	Notropis telescopus	83	14	15	54	0	83
	bigeye chub	Notropis amblops	126	10	16	58	0	84
Mussel	Asian clam	Corbicula fluminea	264	11	13	61	0	85
	slippershell mussel	Alasmidonta viridis	105	9	12	64	1	86
	elktoe	Alasmidonta marginata	176	8	16	63	0	87
Fish	least brook lamprey	Lampetra aepyptera	84	13	16	59	1	89
	freshwater drum	Aplodinotus grunniens	347	6	13	71	1	91
Mussel	ellipse	Venustaconcha ellipsiformis	158	5	9	80	0	94
	mapleleaf	Quadrula quadrula	355	7	7	80	0	94
Fish	longnose gar	Lepisosteus osseus	340	11	13	71	1	96
Mussel	pimpleback	Quadrula pustulosa	330	6	10	81	0	97
	flutedshell	Lasmigona costata	200	9	19	70	0	98
	rainbow	Villosa iris	103	16	18	65	0	99

Appendix F, Continued.

Mussel	white heelsplitter	Lasmigona complanata	325	9	8	82	0	99
Crayfish	grassland crayfish	Procambarus gracilis	324	5	7	86	1	99
Fish	bigeye shiner	Notropis boops	181	10	18	73	0	101
	blackstripe topminnow	Fundulus notatus	227	8	6	87	0	101
	rosyface shiner	Notropis rubellus	200	10	19	72	0	101
	warmouth	Chaenobryttus gulosus	191	15	6	81	0	102
Mussel	yellow sandshell	Lampsilis teres	395	8	9	85	0	102
Fish	bigmouth buffalo	Ictiobus cyprinellus	370	8	13	82	1	104
Mussel	pistolgrip	Tritogonia verrucosa	359	7	14	86	0	107
	Ouachita kidneyshell	Ptychobranchus occidentalis	110	16	14	77	1	108
Fish	bigmouth shiner	Notropis dorsalis	270	6	8	93	2	109
	grass pickerel	Esox americanus	105	20	12	77	2	111
	greenside darter	Etheostoma blennioides	199	12	20	81	0	113
Mussel	threeridge	Amblema plicata	359	10	14	89	0	113
Fish	bleeding shiner	Luxilus zonatus	153	13	18	83	0	114
	creek chubsucker	Erimyzon oblongus	101	19	22	73	0	114
	northern hog sucker	Hypentelium nigricans	223	11	21	82	0	114
	black redhorse	Moxostoma duquesnei	218	12	20	84	0	116
Mussel	pondhorn	Uniomerus tetralasmus	322	4	11	99	2	116
Fish	stippled darter	Etheostoma punctulatum	123	21	10	85	3	119
Mussel	little spectaclecase	Villosa lienosa	112	17	17	83	2	119
Crayfish	papershell crayfish	Orconectes immunis	313	6	9	103	1	119
Fish	suckermouth minnow	Phenacobius mirabilis	430	5	8	108	1	122
	golden redhorse	Moxostoma erythrurum	310	9	15	99	0	123
	white crappie	Pomoxis annularis	461	9	14	102	2	127
Mussel	fragile papershell	Leptodea fragilis	415	11	14	104	0	129
	Wabash pigtoe	Fusconaia flava	404	9	17	106	0	132
Fish	rainbow darter	Etheostoma caeruleum	176	17	22	94	0	133
	Johnny darter	Etheostoma nigrum	334	8	7	119	0	134
	shorthead redhorse	Moxostoma macrolepidotum	385	14	20	100	0	134
	logperch	Percina caprodes	328	10	12	117	0	139
	smallmouth bass	Micropterus dolomieu	268	12	22	105	0	139
	brook silverside	Labidesthes sicculus	330	15	14	115	0	144
	channel catfish	Ictalurus punctatus	505	12	16	116	1	145
	fathead minnow	Pimephales promelas	373	8	10	131	2	151
	banded sculpin	Cottus carolinae	192	18	21	113	0	152
	slender madtom	Noturus exilis	280	17	18	117	0	152
	largescale stoneroller	Campostoma oligolepis	208	20	22	111	0	153
	gizzard shad	Dorosoma cepedianum	474	18	21	115	1	155
	northern studfish	Fundulus catenatus	216	20	21	115	0	156
	sand shiner	Notropis stramineus	429	9	8	138	2	157
Crayfish	golden crayfish	Orconectes luteus	262	18	21	127	1	167
Fish	blackspotted topminnow	Fundulus olivaceus	236	23	22	123	0	168
	striped shiner	Luxilus chrysocephalus	226	22	25	122	0	169
	golden shiner	Notemigonus crysoleucas	427	9	14	146	1	170
	red shiner	Cyprinella lutrensis	441	9	8	153	1	171
Mussel	plain pocketbook	Lampsilis cardium	430	14	25	134	0	173
Crayfish	spothanded crayfish	Orconectes punctimanus	143	31	27	112	3	173
Fish	Ozark minnow	Notropis nubilus	202	27	24	127	0	178

Appendix F, Continued.

Fish	orangespotted sunfish	Lepomis humilis	483	11	16	150	2	179
	western mosquitofish	Gambusia affinis	387	22	17	150	1	190
	hornyhead chub	Nocomis biguttatus	216	30	25	137	2	194
	southern redbelly dace	Phoxinus erythrogaster	208	35	24	137	3	199
	common carp	Cyprinus carpio	563	20	23	174	1	218
Crayfish	devil crayfish	Cambarus diogenes	456	23	23	175	0	221
Fish	longear sunfish	Lepomis megalotis	309	30	28	166	2	226
Mussel	lilliput	Toxolasma parvus	482	20	24	189	1	234
Fish	fantail darter	Etheostoma flabellare	284	36	29	171	1	237
Mussel	paper pondshell	Utterbackia imbecillis	502	14	25	206	1	246
Fish	redfin shiner	Lythrurus umbratilis	450	22	22	208	1	253
Mussel	creeper	Strophitus undulatus	499	20	30	203	1	254
Fish	orangethroat darter	Etheostoma spectabile	355	33	20	201	4	258
	yellow bullhead	Ameiurus natalis	458	30	29	206	2	267
Crayfish	virile crayfish	Orconectes virilis	483	24	23	233	2	282
Fish	black bullhead	Ameiurus melas	522	28	26	241	2	297
	largemouth bass	Micropterus salmoides	578	30	31	244	2	307
	white sucker	Catostomus commersoni	475	32	28	252	4	316
	bluntnose minnow	Pimephales notatus	531	41	33	274	2	350
Mussel	pondmussel	Ligumia subrostrata	514	40	32	276	4	352
Fish	creek chub	Semotilus atromaculatus	510	41	36	272	4	353
	central stoneroller	Campostoma anomalum	515	44	34	276	4	358
Mussel	giant floater	Pyganodon grandis	563	43	33	278	4	358
	fatmucket	Lampsilis siliquoidea	506	44	36	276	4	360
Fish	green sunfish	Lepomis cyanellus	583	49	37	290	5	381
	bluegill	Lepomis macrochirus	584	49	37	291	5	382

APPENDIX G

Summary of the training sessions put on by staff at the Missouri Resource Assessment Partnership from 1999-2003

Dates of Training	Location	Participants	Agency
March 8-10, 1999	Columbia, MO	Jeff Quinn	Arkansas Game and Fish Commission
		Tracy Ford	Arkansas Game and Fish Commission
		Brian Wagner	Arkansas Game and Fish Commission
		Donald Schrupp	Colorado Division of Wildlife
		Billy Schweiger	EPA Region 7
		Ted Hoehn	Florida Fish and Wildlife Commission
		Randy Kautz	Florida Fish and Wildlife Commission
		Liz Kramer	University of Georgia
		Kevin Kane	Iowa State University
		Kelly Arbuckle	Iowa State University
		Dave Day	Illinois Dept. of Natural Resources
		Forrest Clark	U.S. Fish and Wildlife Service
		Dana Limpert	Maryland Department of Natural Resources
		Sharon Sanborn	U.S. DoD, Fort Leonardwood, MO
		Ralph Haeffner	U.S. Geological Survey-Water Resource Division
		John Tertuliani	U.S. Geological Survey-Water Resource Division
		Chuck Berry	South Dakota State University
		Bob Greenlee	Virginia Department of Game & Inland Fisheries
		Leslie Orzetti	U.S. DoD, Legacy Program
Feb 24-25, 2000	Columbia, MO	Steve Wall	South Dakota State University
		Chad Kopplin	South Dakota State University
Aug 28-29, 2000	Orono, ME	Cindy Loftin	University of Maine
		Dave Courtemanch	Maine Dept. of Environmental Protection
		Dan Coker	Maine Natural Areas Program
Oct 29-30, 2001	Columbia, MO	Jim Peterson	GA Cooperative Fish and Wildlife Research Unit
		1 Graduate student	GA Cooperative Fish and Wildlife Research Unit
Nov 13-14, 2001	Columbia, MO	Robin McNeely	Iowa State University
		Patrick Brown	Iowa State University
Feb 8-9, 2002	Columbia, MO	Keith Gido	Kansas State University
		2 Graduate students	Kansas State University
April 1-2, 2002	Columbia, MO	Ann Hogan	Illinois Dept. of Natural Resources
		Chad Dolan	Illinois Dept. of Natural Resources
Aug 8-9, 2002	Columbia, MO	Geoff Henebry	University of Nebraska
		1 Graduate student	University of Nebraska
Oct 29-30, 2002	Columbia, MO	Jana Stewart	U.S. Geological Survey-Wisconsin
		Alex Covert	U.S. Geological Survey-Ohio
		Stephanie Kula	U.S. Geological Survey-Ohio
		Donna Meyers	U.S. Geological Survey-Ohio
		Allain Rasolofoson	U.S. Geological Survey-Michigan
		Kurt Kowalski	U.S. Geological Survey-Michigan
		Steve Achele	U.S. Geological Survey-Michigan

Appendix G, Continued

Oct 29-30, 2002	Columbia, MO	Ed Bissell	U.S. Geological Survey-Michigan
		Jim McKenna	U.S. Geological Survey-New York
		Dora Passino-Reader	U.S. Geological Survey-New York
		Kirk Lohman	U.S. Geological Survey-Minnesota, Illinois
		Daniel Fitzpatrick	U.S. Geological Survey-Minnesota, Illinois
		Chris Smith	Wisconsin Dept. of Natural Resources
		Lizhu Wang	Wisconsin Dept. of Natural Resources
		Paul Seelbach	Michigan Dept. of Natural Resources
July 16-17, 2003	Denver, CO	Don Schrupp	Colorado Division of Wildlife
		Shannon Albeke	Colorado Division of Wildlife
		Nathan Nibbelink	University of Wyoming
		Douglas Beard	U.S. Geological Survey-GAP, NBII